ANNUAL REPORT

OF THE

DIRECTOR
BUREAU OF STANDARDS

TO THE

SECRETARY OF COMMERCE

FOR THE

FISCAL YEAR ENDED JUNE 30, 1921

(Miscellaneous Publications—No. 47)

WASHINGTON
GOVERNMENT PRINTING OFFICE
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Washington, D. C.

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STANDARDS

and their intercomparison, improvement, and application in science, engineering, industry, and commerce.

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REPORT

OF THE

DIRECTOR, BUREAU OF STANDARDS.

DEPARTMENT OF COMMERCE,
BUREAU OF STANDARDS,
Washington, July 1, 1921.

SIR: There is submitted herewith a report of the work of the Bureau of Standards for the fiscal year ended June 30, 1921.

I. FUNCTIONS, ORGANIZATION, AND LOCATION.

Before describing in detail the various scientific and technical problems in which the Bureau of Standards is engaged the following brief statement as to its functions and organization may be helpful to those unfamiliar with the subject of standardization in its broad and modern sense.

The standards with which the Bureau is authorized to deal may be conveniently classed as follows: Standards of measurement, standard values of constants, standards of quality, standards of mechanical performance, and standards of practice.

1. DEFINITION OF STANDARDS.

Standards of Measurement.

A standard of length may be taken as an example of a standard of measurement. It must be a length which is unchanging, reproducible, and capable of being compared with the working standards used in the most precise scientific work or with those used in commerce and industry. In order to carry out such comparisons, working standards must be prepared which are subdivisions and multiples of the fundamental standard, and this process of subdividing and multiplying the standard involves difficulties as great as those met with in the preparation of the fundamental standard itself.

The construction of a set of standard weights from a single unit is also an illustration; a whole set of standard weights must be prepared before the standard weight of the Government can become available to the public. Before these working standards, made up of subdivisions and multiples of the fundamental standard, can be prepared questions as to the methods of comparison arise, which again involve the solution of difficult scientific problems in connection with the balance or the methods used. These balances range from that

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STANDARDS

1

STANDARDS OF MEASUREMENT

Reference and working standards for measurements of all kinds, including fundamental and derived STANDARDS OF MEASUREMENT for expressing the quantitative aspects of space, time, matter, energy, motion and of their interrelations.

By definition, specification, or material standard, covering, for example, length, area, and volume; mass, weight, density, and pressure; heat, light, electricity, and radioactivity, including quantity, flux, intensity, density, etc.

2

STANDARD CONSTANTS

Natural standards or the measured numerical data as to materials and energy, known as physical or STANDARD CONSTANTS, i. e., the fixed points or quantities which underlie scientific research and industrial processes when scientifically organized.

Mechanical equivalent of heat, light, and electricity and of gravitation; specific densities; viscosities; melting and boiling points; heat capacity; heats of combustion; velocity of propagation of light; conductivities of materials to heat and light; electrochemical and atomic weights and many similar magnitudes determined experimentally with maximum precision and referred to fundamental standards of measure.

3

STANDARDS OF QUALITY

Specifications for material (by description, sample, or both), known as STANDARDS OF QUALITY, fixing in measurable terms a property or group of properties which determine the quality.

The numerical magnitude of each constituent property pertinent to the quality involved, and specific magnitude in units of measure of such significant factors as uniformity, composition, form, structure, and others.

4

STANDARDS OF PERFORMANCE

Specification of operative efficiency or action, for machines and devices, STANDARDS OF PERFORMANCE, specifying the factors involved in terms susceptible of measurement.

Numerical statement of speed, uniformity, output, economy, durability, and other factors which together define the net efficiency of an appliance or machine.

5

STANDARDS OF PRACTICE

Codes and regulations impartially analyzed and formulated after study and experiment into STANDARDS OF PRACTICE for technical regulation of construction, installation, operation, and based upon standards of measurement, quality, and performance.

Collation of standard data, numerical magnitudes, and ranges of the pertinent factors defining quality, safety, economy, convenience, and efficiency.

PURPOSE

To aid ACCURACY IN INDUSTRY through uniform and correct measures;
To ASSIST COMMERCE IN SIZE STANDARDIZATION of containers and products;
To PROMOTE JUSTICE IN DAILY TRADE through systematic inspection and regulation;
To facilitate PRECISION IN SCIENCE and TECHNOLOGIC RESEARCH through calibration of units, measures, and instruments involved.

To SERVE as an EXACT BASIS for scientific study, experiment, computation, and design;
To FURNISH an EFFICIENT CONTROL for industrial processes in securing reproducible and uniformly high quality in output;
To SECURE UNIFORMITY OF PRACTICE in graduating measuring instruments, compiling tables, in standards of quality and performance, and wherever uniformity is desirable;
To AID LABORATORY RESEARCH BY REDUCING ERRORS and uncertainty caused by use of data of doubtful accuracy.

To secure HIGH UTILITY in the PRODUCTS of industry by setting an attainable standard of quality;
To furnish a SCIENTIFIC BASIS for FAIR DEALING to avoid disputes or settle differences;
To PROMOTE TRUTHFUL BRANDING and ADVERTISING by suitable standards and methods of test;
To PROMOTE PRECISION and AVOID WASTE in science and industry by affording quality standards by which materials may be made, sold, and tested.

To CLARIFY THE UNDERSTANDING between maker, seller, buyer, and user, as to operative efficiency of appliances and machines;
To make EXACT KNOWLEDGE THE BASIS OF the buyer's choice;
To STIMULATE AND MEASURE MECHANICAL PROGRESS.

To FURNISH for each utility a single IMPERSONAL STANDARD of practice as a BASIS FOR AGREEMENT of all interests clearly defined in measurable terms;
To INSURE EFFECTIVE DESIGN and INSTALLATION of utilities of all kinds;
To PROMOTE SAFETY, EFFICIENCY, and CONVENIENCE in the maintenance and OPERATION of such utilities;
To SECURE UNIFORMITY OF PRACTICE where such is practicable, and EFFECTIVE ALTERNATES in other cases.

capable of measuring the thousandth part of a milligram to the large testing machine capable of measuring a load of thousands of tons. The complete range must be covered, which involves not only a large number of working standards, all of which must agree with the fundamental standard, but apparatus suitable for the comparison of these standards with all of the lengths or weights found in practice. These steps and equipment are absolutely essential in order to secure uniform measurements of length or weight throughout the country, and they have their counterpart in every quantity that has to be measured, whether it be length, weight, temperature, heat, light, or the various electrical measurements or other standards of measurement. These standards in one form or another are involved in practically every scientific investigation, industrial process, engineering structure, or commercial transaction.

Physical Constants (Standard Values).

There are many fixed relations between physical quantities, the values of which it is extremely important to know. These values are usually termed "physical constants" and are used in every branch of scientific work or industry. The amount of heat required to change a pound of water into steam under normal conditions and the relation between heat and mechanical energy are two important physical constants. Their values are used in practically every computation in connection with the designing of steam engines and boilers, the tests of their efficiencies, or the measurement of their output. The amount of heat required to turn liquid ammonia into vapor or the amount of heat required to melt a pound of ice are constants equally important in the refrigerating industries. The value of the relation between electrical and mechanical energy is involved in many commercial transactions concerned in electricity.

Accurate and authoritative values of these constants are just as essential as in the case of standards of measurement. Many of those now in use are old and obsolete and need redetermination by means of the best modern facilities for physical measurement. Their determination involves the most difficult and precise work in all branches of physics and chemistry—a fact not generally known by those not engaged in the scientific or technical work where these constants are used.

Standards of Quality.

A standard of quality for a given material may sometimes take the form of a sample of that material with which other materials of the same kind can be compared, but this is generally a makeshift of the poorest sort. It is only resorted to in the absence of definite and reliable specifications in terms of measurable properties; that is to say, a standard of quality of a material usually takes the form of a specification or definition of its properties, involving, of course, the measurement of those properties by means of the usual standards of measurement. A certain kind of steel, a cement, a paint, an oil, a paper, or a cloth is found by use to be good or poor for a definite purpose. The questions then arise: Why is it good or poor? What are the physical or chemical properties or the particular combination of elements which make it of good or poor quality? How are its

properties to be measured or its constituents determined? These are questions for the laboratory to answer and involve physical and chemical investigations of the most difficult sort.

A standard of quality for a given material necessarily takes into account the purpose for which the material is to be used. To set the standard too low results in losses, poor efficiency, and even loss of life; to make it too high may result precisely in the same thing; that is to say, the material must be suitable for the purpose intended, and the Bureau's investigations in connection with the properties of materials are to enable the user of these materials, first, to select intelligently the material best suited for the purpose; second, to specify it in terms which the producer can not mistake; and, third, to make the necessary tests to ascertain whether or not the material supplied is in accordance with the specifications.

The actual testing of materials by the Bureau of Standards to ascertain whether or not they comply with specifications is confined almost exclusively to Government purchases, but in making these tests (in which the Bureau has had the hearty cooperation of practically all the departments of the Government service) it is compelled to make many investigations concerning the properties of materials, their specification, and measurement. While this work is of great value in placing Government purchases on a correct business basis, the results of the investigations as to the properties of materials and the information gained in testing Government supplies are even more important to the general public and are distributed in the form of suitable publications.

The Bureau does not compete with private testing laboratories, but endeavors to assist them by the development of standard specifications, methods of measurement, and other matters where uniformity is desirable, much of which information, as stated above, is secured in connection with the testing of materials purchased by the Government and a close observation of their use.

The time is not far distant when it will be required that all material bought and sold shall be as represented, but it should be kept in mind that this is impossible except in the case of those materials for which proper standards of quality and methods of measurement have been developed. It must not be assumed that the purchaser or user is the only party benefited in the development of such standards. On the contrary, the manufacturer, first of all, is interested in all things which affect the quality of his product. The research work and tests conducted by the Bureau have done a great deal in pointing out those properties upon which the quality of a material depends, and in connection with this work it is worth while to remember that not only are the important properties pointed out, but the ways for measuring them are indicated. The facilities of the Bureau are not extensive enough to permit it to conduct all the research work in which the manufacturers of this country would like it to engage, but the value and importance of its work along these lines is becoming more and more appreciated and is being extended each year.

Standards of Performance.

The value of an instrument, device, or machine almost always depends upon the efficiency of its performance. In such cases it is necessary to state the performance desired or guaranteed in terms

which are correct and susceptible of measurement. As in the case of standards of quality, the standard involved is more often in the form of a specification, but specifications are useless unless based upon correct scientific and mechanical principles and supplemented with a statement of the method to be used in ascertaining whether or not the specification or guaranties have been complied with.

The performance of an engine or boiler, a pump, an electrical generator or motor, a weighing device, or a telescope can usually be measured, but the quantities to be measured and the methods used must be specified correctly and understood by all the parties concerned in the construction, purchase, or use of such apparatus. To secure information upon which to base proper standards of performance involves investigations quite as scientific in character and as difficult as in the case of other standards, as well as a knowledge of technical and manufacturing processes. In this field, as well as in the field dealing with the properties of materials, the Bureau has had the hearty cooperation of the various Government experts, manufacturers, engineers, and technical societies. It has conducted many investigations which have led to improvements in machinery, appliances, and manufacturing processes.

Standards of Practice.

Standards of practice are generally involved in the enactment of laws when technical and scientific matters are concerned, in the ordinances relating to the regulation of public utilities, and in the establishment of building and safety codes. Like standards of performance, they are dependent upon standards of measurement and standards of quality and are of the most vital importance in questions pertaining to the welfare and safety of the public. In a field so broad the Bureau can only touch upon the more important aspects of the work, where national uniformity is desired—fields which are not covered in private laboratories.

2. RELATION OF THE BUREAU'S WORK TO THE PUBLIC.

Comparison of Standards of Scientific and Educational Institutions or of the Public with Those of the Bureau.

It is perfectly obvious, even to one unfamiliar with the subject, that the maintenance on the part of the Government of correct standards of measurement or quality or performance calls for continuous scientific and technical investigations of the highest grade, involving the most competent expert services and the best scientific equipment. When this is accomplished, there still remains the serious problem of making the results available and useful to the public.

The Bureau compares with its own standards of measurement the standards and measuring instruments of States, cities, scientific laboratories, educational institutions, or the public, for which a nominal fee is charged, except in the case of the National and State Government institutions. It is at all times glad to assist these institutions in matters concerning these standards or their use, whether it be in connection with the enactment of laws, regulations, or ordinances concerning the weights and measures of everyday trade or in connection with precision standards used in scientific work.

Work of the Bureau in an Advisory Capacity.

The Bureau serves in an advisory capacity for those officials of the States and municipalities charged with the administration of the laws governing weights and measures. Likewise its advice is freely given concerning the use of exact standards in all lines of commercial activity. This information is of the first importance to many of our industries. As an example it may be stated that the success or failure of an industrial enterprise may depend upon the securing of correct information concerning the control of temperature, advice which can be secured only from such an institution as the Bureau.

A great many inquiries are also received concerning the use of the various materials of construction, and the Bureau has frequently assisted in the preparation of specifications on which to base the purchase of materials of this kind.

Many questions of disagreement between the public and utility companies as to matters involving the use of standards are referred to the Bureau for advice or adjustment, often avoiding unfair and inconsistent regulations, as well as long-drawn-out and expensive litigation. There is a great need on the part of the public for unbiased and reliable information pertaining to the standards entering into the regulation and sale of the services of public utilities. As far as possible such information is given in the form of publications upon definite subjects.

In the formulation of safety codes, designed to govern electrical and other construction, the Bureau has taken an active part, particularly in the collecting and study of data, upon the correct interpretation of which the success of such regulations must always depend.

3. RELATION OF THE BUREAU'S WORK TO THE INDUSTRIES.

Assistance in Establishing Exact Standards of Measurement Needed in Industries.

It must not be inferred from the above that the Bureau's activities are devoted principally to the interests of the user or consumer. The fundamental facts regarding standards of measurement, quality, or performance are the very things which most deeply concern manufacturers; they are fundamentally concerned, either directly or indirectly, with the improvement of methods of production or the quality of the output. It may be said that the Bureau occupies somewhat the same position with respect to the manufacturing interests of this country that the bureaus of the Department of Agriculture do to the agricultural interests. Many industries realize the importance of scientific investigation which, in practically every case, involve some kind of precision measurement.

It is upon quality as well as upon price that competition must finally depend, whether in domestic or foreign commerce. The use of exact methods and scientific results is the greatest factor in the improvement of quality, efficiency, or the development of new industries. The educational value of the Bureau's work in this respect is almost entirely unknown to the general public, and yet the Bureau receives hundreds of letters, as well as many personal visits, from

manufacturers seeking information as to standards of measurement, how to use them, how to measure the properties of materials, or as to the fundamental, physical, and chemical principles involved; also, what is of even greater importance, how to initiate and carry out scientific investigations and tests on their own account in their particular fields of work.

The importance of maintaining scientific institutions having to do with standardization and the application of precise measurements to the industries has been recognized by all the leading countries of the world. Great Britain maintains the Standards Department of the Board of Trade, which is in charge of the standards and inspection service of the trade weights and measures; also the National Physical Laboratory, whose functions include matters pertaining to scientific and technical standards, physical constants, and to some extent the properties of materials. The Laboratoire d'Essais of France, while not as extensive as the English institution, is charged with similar duties. Germany maintains three such institutions—the Normal-Eichungs Kommission, equipped with the buildings, personnel, and apparatus necessary in standardizing and controlling the weights and measures of trade; the Physikalisch-Technische Reichsanstalt, covering testing and investigations in connection with scientific and technical standards other than weights and measures; and the Materialprüfungsamt of the Prussian Government, a large institution devoted to the investigating and testing of structural, engineering, and other materials. It is generally recognized that these institutions have been exceedingly important factors in the industrial progress of these countries.

The Collection of Fundamental Data for the Industries.

During the past year[5] the Bureau has continued its close cooperation with American industries. Recently a large number of firms have entered upon the manufacture of goods formerly produced only in foreign countries, and in this work (much of which is of a pioneer nature in the United States) hundreds of important questions concerning methods of measurement and the properties of materials have required solution. In numerous cases the Bureau has helped to solve these problems through special investigations conducted in its laboratories, the results of which have been freely given to the industries, with the result that improved processes have been adopted, resulting in a more satisfactory product and more economical method of production.

Simplification of Standards.

An extremely important matter in which the Bureau is interested is the simplification of industrial products through the elimination of useless sizes, unnecessary variations in the composition of materials intended for the same purpose, and the removal of unprofitable restrictions upon output through poorly prepared or obsolete specifications. The small sum necessary to carry on work in connection with simplification of this sort will be returned manyfold in the increased efficiency of the industries benefited.

To illustrate the need of this work, it is only necessary to consider that in the majority of our industries many sizes and styles of material and devices have come into use, not through any real demand

for such a variety of equipment but through the undirected natural expansion of the business. The keeping of so many sizes and styles in stock is a source of unnecessary expense. Several investigations recently conducted by the Bureau have shown that large sums of money can be saved in several of our manufacturing industries by simplification of this sort. Such standardization can best be carried out by an unbiased third party working in cooperation with manufacturers and users. This fact is generally recognized by the industries, which are only too willing to cooperate in every way possible.

Elimination of Industrial Wastes.

In cooperation with the industries of the country the Bureau is assisting in the great problem of the elimination of industrial wastes, which, like all major problems, depends for its solution upon correct fundamental scientific and technical data. For many years the Bureau has kept in touch with industrial processes and has acted as a clearing house for certain kinds of information concerning improvements in methods of production. It has assisted in the preparation of specifications, codes, and ordnances, all having for their primary object the increasing of industrial efficiency. Through its researches ways and means have been found for the better utilization of our raw materials, for cheapening and improving the quality of manufactured articles, and for turning to useful purposes the by-products of industrial plants. A long list of investigations directly bearing on this subject, which are now in progress in the Bureau's laboratories, might be cited, but it is only necessary to state that along each one of these lines great savings are possible, compared to which the small sums expended for the necessary research work are insignificant.

It is worth while to mention in this connection that the Bureau's position in the industrial field is such that any suggestions which it makes concerning methods for increasing efficiency are always well received.

Training of Experts in Various Industrial Fields.

One of the greatest services which the Bureau performs for the industries is the training of men for scientific and technical research work. Many young men receive what is, in some respects, better than a postgraduate course by working in some of the minor scientific positions at the Bureau during the years immediately following the completion of their college course. These men then go into the industries with a better conception of the problems of research work.

In this connection it should be mentioned that while the entrance salaries in these lower-grade positions are perhaps sufficient those paid the more experienced members of the scientific staff are wholly inadequate. This has resulted in the present difficulty of retaining the most valuable men in the Government service. It is assumed that as soon as possible this unsatisfactory condition will be remedied and the salaries of these experts placed more on a plane with the compensation for similar work in industrial and even educational institutions. Unless steps are taken to meet this situation it will be impossible to maintain the Bureau's staff on the high plane of efficiency which it has always occupied.

4. RELATION OF THE BUREAU'S WORK TO THE GOVERNMENT.

Comparison of Standards of Other Government Departments with Those of the Bureau.

The use of exact standards enters into every branch of the Government service, as it does into every industry and into the everyday life of all persons. It was in the Government service, however, that the need for exact standards was first appreciated. The work done for the Government is in nowise different from that carried on for individuals and involves the same problems.

Many bureaus of the Government service are charged with the administration of laws and the establishment of regulations, the intelligent application of which depends very largely on the use of exact standards. This is true to a greater extent than is generally supposed. The Bureau of Standards has cooperated freely with these branches of the Government, and the service rendered has involved every department of physics and chemistry covered by the Bureau's activities. The neglect of such matters in the past has been a frequent source of misunderstanding and litigation between the Government service and the public. Conspicuous examples of bureaus to which assistance has been given are the Customs and Internal-Revenue Services, Steamboat-Inspection and Coast Guard Services, and the Bureau of Navigation of the Department of Commerce, as well as all bureaus of the War and Navy Departments engaged in construction or development work.

Performance of Tests and Investigations and the Collection of Scientific Data of a Fundamental Nature.

The engineering and building construction in progress at all times by the Government is exceedingly great, both in variety and magnitude. In all of it a knowledge of the materials employed is of fundamental importance from the standpoints of economy, efficiency, and safety. The work of investigating the properties of structural materials was taken up and is carried on primarily for the purpose of securing the information needed by the Government service in its structural work. This information is necessary to the public in construction work, and every effort is made by the Bureau to render its findings available to the public generally. The demands for information of this sort have come from practically all Government bureaus and establishments, but especially in connection with the structural work carried on by the Office of the Supervising Architect, the engineering branches of the Army, the Bureau of Construction and Repair of the Navy, the Panama Canal, and the Reclamation Service.

Advisory and Consulting Capacity.

One of the most important services which the Bureau has been able to render to other departments of the Government, both civil and military, has been of an advisory and consulting nature in matters pertaining to the scientific work in which these departments are interested. Too great emphasis can not be placed on the importance of this phase of the Bureau's work. Its maintenance would

be warranted for this reason alone, even though its usefulness in this field is but a small portion of the total service which it has rendered other branches of the Government.

The Bureau's laboratories have been open and its experts available at all times to every department of the Government, and in many cases substantial help has been rendered to the military and civil departments through the familiarity of the Bureau with certain kinds of work and its ability to quickly decide whether the particular methods, materials, or devices were suitable for the service in question.

The Bureau as a Testing Laboratory and Its Work in the Preparation of Specifications on Which to Base the Purchase of Materials.

The Bureau of Standards serves as a testing bureau for the various departments of the Government when called upon; and, as such, is assisting to place Government purchases upon an economical and businesslike basis. The example of the Government in such matters has a far greater influence upon the public than is generally supposed. The Government can do no greater service to the country than to place its own purchases upon a basis which may be taken as a standard by the public at large. This work involves the specification of a wide range of structural and miscellaneous materials and their testing, when delivered, to ascertain whether or not they comply with the specifications. This is especially important, since such materials are purchased by means of competitive bids, a method resulting in much fraud and injustice unless suitable standards are established and successful bidders held absolutely to this standard in making deliveries. Furthermore, most purchasing officers are realizing the great importance of having such testing done by a disinterested institution equipped with the scientific and other facilities for performing the service in a manner that is fair to both parties concerned in the purchases.

Among the Government bureaus and establishments which have utilized the Bureau of Standards as a testing institution in connection with the purchase of supplies may be mentioned the Government Printing Office, in connection with the purchase of paper, inks, and printing supplies, and the Post Office Department, in connection with the purchase of paper, twine, textiles, etc. A wide range of materials has been tested for the Quartermaster Corps of the Army, the Bureau of Supplies and Accounts of the Navy, and the Panama Canal. The General Supply Committee has called upon the Bureau for assistance in the specification of all sorts of supplies and equipment, as well as the testing of samples submitted by bidders of the supplies bid upon. Practically every branch of the Government service, including the District of Columbia, utilizes the Bureau of Standards as a testing bureau. Here, again, as in other fields of the Bureau's activities, it gains much useful knowledge, which is given to the public in the form of suitable publications.

5. ORGANIZATION.

The organization of the Bureau's scientific and technical staff is based upon the nature of the expert service involved rather than

upon the classes of standards. For example, the Division of Weights and Measures has to do with all matters pertaining to standards of length, mass (weight, as it is commonly termed), time, density, and similar questions, whether they arise in connection with the precision standards used in scientific investigation, the master standards of manufacturers, or the ordinary weights and measures of trade. A standard of quality or performance where any of the above measurements form the fundamental and most important factor would be referred to this division.

The Division of Heat and Thermometry has to do with heat standards, the testing of heat-measuring apparatus, the determination of heat constants, of which there are many, and all investigations pertaining to quality or performance where heat measurement is the essential and predominating factor.

Similarly, the Electrical Division is concerned with all the electrical problems that may be taken up at the Bureau, whether in connection with the various electrical standards of measurement, electrical constants, the electrical properties of materials, or the performance of electrical equipment.

Questions in optics enter into standards of all kinds to a greater extent than has been supposed. Hence, there is an Optical Division provided, with experts in spectroscopy, polarimetry (used in sugar analysis), color measurement, the principles of optical instruments, and the measurement of the optical properties of materials.

Practically all investigations concerning the various classes of standards involve chemistry in one form or another. There are also many chemical standards and questions which arise in connection with chemical work generally, especially in the industries. Hence, there is a Chemical Division, cooperating with every other division of the Bureau, as well as taking care of the questions of a purely chemical nature that come to the Bureau and which fall within its functions.

In the case of the more important technical fields, divisions have been formed dealing more specifically with large and important classes of materials, but many of the purely scientific questions involved would be handled by one of the above-mentioned scientific divisions or jointly with it. The work of the technical divisions is just as scientific in character, but deals more specifically with manufactured products.

The work of the Structural Engineering and Miscellaneous Materials Division includes the investigation, testing, and preparation of specifications for these materials, such as the metals and their alloys, stone, cement, concrete, lime, the clay products, paints, oils, paper, textiles, rubber, and other miscellaneous materials.

The Division of Engineering Physics makes investigations and tests regarding the performance and efficiency of instruments, devices, and machinery. This work includes the testing of water and other meters, aeronautic instruments, etc., as well as investigations in aerodynamic physics and the study of sound.

Questions pertaining to the manufacture, specifications, testing, and use of the metals and their alloys is so important that a separate division, known as the Metallurgical Division, is provided to deal with these problems.

The Ceramic Division is concerned with all problems in connection with the use of clays and clay products, with investigations in the field of glass manufacture, and with questions involving the use of refractory materials and enameled metals.

The employees engaged in clerical work, purchasing, files, records, and accounting, as well as those of the library and information section, form the Office Division, while those employed in the operation of the mechanical plant, the various shops, and the care of the buildings and grounds make up the Engineering and Construction Division.

6. LOCATION.

The laboratories and offices of the Bureau of Standards are located on a tract of about 35 acres in the northwest section of Washington, on Pierce Mill Road, near Connecticut Avenue, and are reached by the Chevy Chase car line. They were placed outside of the business center of Washington in order to insure freedom from mechanical, electrical, and other disturbances common to the business and more thickly populated sections of a city. Furthermore, the area of ground necessary precluded a site nearer the city. It has been found by experience that the efficiency of the employees, especially those engaged in testing and scientific investigation, has been greatly increased by the location of the laboratories in a section free from the ordinary disturbances of metropolitan life.

II. SCIENTIFIC AND TECHNICAL DIVISIONS.

1. WEIGHTS AND MEASURES.

The Division of Weights and Measures is concerned with measurements involving the fundamental units of length, mass, and time, and such derived or secondary units as area, volume, density, and pressure. The activities of the division also include preparation of specifications and tolerances for use in connection with standardization of weighing and measuring apparatus, gauges, and screw threads; cooperation with States in the preparation and enforcement of weights and measures legislation; the design, improvement, and inspection of weights and measures apparatus, the carrying out of researches designed to result in more accurate knowledge of physical constants and improvements in engineering practice.

GENERAL.

The Importance of Weights and Measures.

The importance of weights and measures in our every-day life will be appreciated only when consideration is given to the many points at which we come in contact with them. Practically everything with which we deal is at some time or other either weighed or measured, and the correctness of our judgement of relative values is dependent largely upon the accuracy of this weight or measure. The price and value of our food, clothing, shelter, fuel, the nicety of fit and adjustment and proper functioning of mechanical products, are all directly or indirectly dependent upon accurate comparative measurements. In fact, all advancement in science, industry, engineering, in civilization itself, is linked with advancement in the art of weighing and measuring.

LENGTH.

Investigations in Precision Length Measurement.

A great deal of time and study have been given to precision length measurements during the year, and the time spent in routine work on the many miscellaneous applications of length measurements which the laboratory has to handle has, by improved methods, been reduced almost to a minimum. The time thus saved has been concentrated on the working out of several problems connected with precision length measurements—in improving the meter comparator, in getting the constant temperature room with its thermostatic control into better condition, in working on problems of best illuminaion of bars with the least amount of heating, with precise focusing, particularly with respect to fine lines which are not properly cut, and in studying the character of the lines. The sources of some apparent discrepanices in length measurements have been thus found and a more exact knowledge of the comparator has been gained, so that conditions can more easily be duplicated and, therefore, it is now possible to check more accurately than heretofore by intercomparison the relative values of the platinum-iridium meters. All of these, except meter 27, the fundamental standard of length of the United States, have been intercompared and calibrated, as well as several of the less important ones.

This investigation of precision measurements by means of the Bureau's comparator, besides giving more reliable information about the present constants of working apparatus, will serve as the preliminary work in the investigation of length measurements by means of the interferometer, a problem which universities and manufacturers are looking to the Bureau to solve and which, on account of its importance, must soon be taken up.

The micrometer microscope is an invaluable instrument in precision measurements, so in this connection one member of the section has undertaken a much-needed investigation of the errors of micrometer-microscope screws. A considerable number of difficulties have been surmounted and results of value to the work of the section have been produced, though only a beginning has been made in the work to be done. Making use of the results obtained from these investigations the Bureau was able to calibrate length standards with a higher average accuracy than before.

There is still a field for much additional work on the Bureau's length standards. For example, the temperature coefficients of the platinum-iridium meter bars should be more accurately redetermined, more work should be done on the problem of proper illumination of lines, and meter number 27, the fundamental standard of the country, should be recompared at the International Bureau.

Status of Standards.

The present status of the section's apparatus and standards is the best that it has been for many years. Recent calibrations, some of which have been mentioned in the preceding paragraph, have yielded important data on the numerical constants and corrections for a large proportion of the equipment. The results in a number of cases have given proof of the need of constant intercomparisons and checking of standards.

Further improvements to be made in the geodetic comparator and the meter comparator will make these of still more service and will also result in increased accuracy. Attention to one or two details and an improved method of moving the microscope on the bench will further improve the apparatus.

Reference to last year's report shows that three instruments were urgently needed: (*a*) Comparator for calibrating the intervals of a graduated standard; (*b*) a small comparator for calibrating sieves and small scales, etc.; (*c*) projection apparatus for testing sieves. The need of all three still exists, but that for the first is the greatest. There is at present but one piece of apparatus in the Bureau for calibrating the intervals of a graduated linear standard of precision, and that is the dividing engine. This, however, is in use practically all of the time on the work for which it was designed and is further limited by the fact that a 1-meter scale can not be calibrated with precision to decimeters on it. This is a condition which should be remedied.

Routine Testing.

As mentioned in a previous paragraph, the time spent on routine testing has been reduced practically to a minimum by improved methods. For example, the improved method of testing and sealing hæmacytometers in lots of about 25 each, it is estimated, takes about

one-eighth of the time required three years ago. The results are fully as dependable and the probability of damage to the chamber or to the cover glasses is reduced. Sieves are now tested in about half the time in which the work was formerly done.

The following articles were tested during the year: Twenty-six length standards and precision scales (yard and meter bars, etc.); 200 tapes (steel, invar, and "reinforced" cloth); 250 sieves; 8 pieces of sieve cloth; 317 hæmacytometers (blood-counting chambers); 489 extra cover glasses for hæmacytometers; 25 level rods; 1 length comparator for gauges, complete; 49 miscellaneous articles tested for length or angle.

The length standards include those of three manufacturers of length-measuring apparatus, that of a foreign Government, and several from State governments. The manufacturers' standards were all calibrated throughout. This, together with the standardization of the Bureau's own apparatus, which is not included above, represents an unusually large amount of work.

The tapes include all varieties, from the precision base-line tapes of the Coast and Geodetic Survey and precision wires of the Department of Geodesy of the Mexican Government to several "reinforced" cloth tapes used by the Department of Commerce for approximate measurements of the holds of ships.

Sieves have been submitted in very large numbers during the past year. The regrettable fact, however, is the large number which have been exceedingly close to the allowable limits in one particular or another rather than close to nominal value.

Indications in the hæmacytometer field are that certified chambers have become quite widely purchased now and present tests are largely for replacements. It is expected that there will be another revival of this work at the time the medical schools open in the fall. A new type of chamber has been submitted to the Bureau in which the glass slide, the ruling surface, and the cover glass supporting surface are of one piece of glass, a decided advance in construction.

A universal comparator built by the Société Genevoise for the measurement of gauges and end standards was completely tested and inspected. The several scales, micrometer screws, and other length-indicating devices on the instrument were calibrated.

Visitors and Travel.

Besides the more or less casual visitors in the section there have been representatives of a number of concerns making or selling instruments or articles tested in this laboratory, also several experts in lines of work very similar to that in this section.

A member of the length section spent a week at Ottawa, Canada, conferring with experts there regarding methods of precision length measurements.

MASS.

Tests.

There were over 6,000 weights tested during the year, an increase of about 14 per cent over the number tested last year. Of these 67 per cent were for private individuals or firms, 23 per cent were for the Federal Government (including tests for other sections of this Bureau), 5 per cent were for State governments, and 5 per cent for educational institutions. Ninety per cent of the weights were in

high-grade analytical sets, such as are commonly used in physical and chemical laboratories. The testing of this class of weights was kept very closely up to date, there being no long delays in any case.

Rejections.

About 3 per cent of the weights submitted were rejected on inspection for special faults of construction or for failure to conform in some particular to the specifications of the Bureau, and about 10 per cent for inaccuracy. The situation is much worse than this would seem to indicate, however, because the large majority of the weights are submitted in sets, and since each set is handled as a unit the loss caused by retesting the sets after they have been corrected is very great. As a result makers have raised the price of weights intended for certification, and there have been requests both for the addition of a new class of a lower grade and for a return to the practice of allowing makers to replace individual weights of a set while they are at the Bureau being tested.

The delays and uncertainties involved in procuring certified weights under present conditions are very serious, and some method of avoiding them would be a benefit not only to the maker and dealer, but also to the users of such weights.

Standards Tested for the States and for Manufacturers.

Standards were tested for the States of Massachusetts, Vermont, West Virginia, and Texas. A set of primary standards was also tested for one of the newer manufacturers of laboratory weights.

Assistance to the Motor Transport Corps.

A large number of weighings have been made to help determine the amount of wear on parts of automobile truck transmissions being tested by the Motor Transport Corps. In a few cases the wear has been masked by some other change, but in the majority of cases the weighings have proved a valuable addition to the measurement of dimensions.

Shortening the Work on High Precision Tests.

A careful study was made of the precision required in the auxiliary observations needed in testing the higher precision laboratory weights. Limits were set as to the permissible range of temperature, humidity, and barometric pressure, and so long as the observations are made within these limits all corrections for the buoyancy of the air can be omitted from the individual weighings and from the customary computations of results, a proper correction being applied to the final value of each weight. Since the work can generally be done within these limits, the work of computing these tests will be very much reduced. A new form of record sheet has been designed for this part of the work which will also help materially to put this testing on a more systematic and efficient basis.

Changes in Weight of Celluloids.

An investigation of the effect of atmospheric humidity on the weight of pyroxalin plastics from three different manufacturers was completed during the year. Weighings of specimens were made at three or four different humidities in a box in which the relative

humidity could be maintained at any desired value. The following facts were noted:

1. All samples showed a loss of weight with age which gradually became slower and which was practically independent of the humidity.

2. There were no appreciable differences in the behavior of "transparent," "ivory," "cream," and "red" samples nor in the samples from the three different makers.

3. The changes in humidity did not cause any permanent change in the samples; the weight rose and fell with the humidity in all cases.

4. The changes were not mere surface effects. The water vapor evidently penetrates into the interior of the sample, so that thick samples continue to gain or lose long after thin samples have reached equilibrium.

5. The change in weight is not proportional to the relative humidity, but is much greater at high humidities than at low humidities for the same change in relative humidity.

6. The total observed changes in weight were a little over 2 per cent for a humidity range of about 30 per cent to 95 per cent.

Standards and Apparatus.

Three of the precision balances were overhauled and readjusted in essential details. The work of overhauling and mounting the highest precision kilogram balance was continued as opportunity could be secured. Fortunately, the pier on which the balance rests is so well isolated that it is apparently free from vibrations, but this was not the case with the mounting for the reading device. After trying many kinds of mountings for the telescope one which gave the desired freedom from vibration and yet maintained a satisfactorily constant zero point was developed and installed.

Further work and tests are still needed before the balance can be relied upon for the character of work for which it is intended. In the meantime the older balance is being used and is sufficiently accurate for the work so far required of it. The apparatus for rapid testing of 50-pound test weights was nearly completed by the instrument shop.

Recommendations.

The most important need for next year is, as last year, the work on the primary standards. It is recommended that the set of platinum-iridium weights from 500 grams down be calibrated at once, and that the older set of gold-plated weights from 1 kilogram to 1 gram be replated and redetermined.

Careful studies as to the accuracy needed in the measurement of barometric pressure have shown that a much more accurate barometer is needed, and it is recommended that a high precision normal barometer be either bought or built. Studies as to the best form of instrument have already been begun, since it is probable that to secure the highest accuracy it will be necessary to design and build the instrument at the Bureau.

TIME.

Investigation of Stop Watches.

On account of the unsatisfactory service which has been obtained in scientific work from stop watches purchased by the Bureau, an

attempt has been made to determine whether the trouble is due to faulty purchase specifications or to poorly designed instruments. As a result of this investigation it has been decided that certain types and models of stop watches are poorly designed and constructed by their respective manufacturers. The specifications have not been changed, but there has been prepared a list of types or models tentatively approved for purchase by the Bureau. This list does not represent the ideal, but merely the best obtainable at this time. Considerable improvement of stop watches is highly desirable for scientific work.

Drum Chronographs.

The drum chronographs which have been supplied the Bureau and used in measuring short-time intervals were unsatisfactory in design. There has recently been located a new source of supply which, it is believed, will answer all requirements.

Advisory Work.

Representatives of the Bureau attended a conference under the auspices of the National Research Council for the horological interests of the country. The purpose of this conference was to discuss methods of overcoming the increasing shortage of watch repairmen which exists throughout the country. The lack of repairmen has resulted in a larger demand for new watches than can be met by the factories. Furthermore, men have left the factories to work in the local shops. As a means of overcoming the scarcity of watch repairmen the industry is planning to have the men certified into various grades. The assistance of the Bureau is contemplated for accomplishing this purpose.

Improvements in Equipment.

A new switchboard was installed for the purpose of distributing either make-circuit or break-circuit signals for use in the laboratories throughout the Bureau, as other sections of the Bureau use the time-signal system of this section extensively.

The Riefler clock, which serves as the precise time standard, was cleaned and oiled and is now performing with its usual high precision, the error being only about 0.01 second per day.

An additional thermostat for maintaining constant temperature in one of the testing cabinets was made and installed.

Routine Testing.

The section has completed the following routine tests:

Class A watches	13
Railroad precision watches	204
Ship watches	454
Comparing watches	23
Stop watches	33
Wrist watches (submitted by War Department)	6,109
Chronometers	2
Miscellaneous	3
Total	6,841

Future Work.

There is so much material awaiting test that it will fully occupy the time of the entire personnel of the section for a number of months without taking into consideration the additional work which may be expected. Much of this, as heretofore, is for other branches of the Federal service and is highly desirable from the standpoint of public economy.

There are three additional investigational problems to which it is desired to call special attention, one is relative to the magnetism of watches, a problem which is always before the trade. The seat of magnetic trouble in watches, and the relation of the magnetizing field to performance of the watches, is unknown. This problem, if undertaken, would necessitate a joint investigation with the Electrical Division.

A problem originated by the Electrical Division and suggested for a joint investigation is the development of an electrically operated clock which does not have an escapement or friction bearing. This investigation offers the possibility of producing a timepiece of unusual precision.

A third problem worthy of being prosecuted is in connection with the new alloy called "elinvar." This alloy has a negligible change of elasticity with temperature and is reported as being suitable for the manufacture of watch hairsprings to be used in connection with solid balance wheels and as producing results superior to those obtained from compensated balances. If a suitable method of application of this alloy can be developed, it will be of material benefit to the general public.

Additional Equipment.

Two additional pieces of equipment are needed. There is great need over the Bureau for a reliable time signal with a signal interval of only a small fraction of a second to supplement the two existing signals of one second and one minute. The other piece of equipment which is needed is a radio receiver for the chronographic registration of radio time signals. This instrument has already been developed by another section of the Bureau. The only expense will be the actual cost of construction and installation.

CAPACITY AND DENSITY.

Research.

An investigation has been carried out on the density of steel and iron under different conditions of manufacture for the Metallurgical Division of the Bureau, the data as obtained being used in some of the work done by that division. Several samples of platinum were examined for density in connection with researches conducted by the Chemistry Division on that metal. This had to do with the purity of the sample and the freedom from entrapped air in the ingot. In some of the work the purity was known and the density was used as the means of indicating the freedom from blowholes, while in other cases the density was an index of the purity of the sample, the ingots having been so cast as to be free from included gases.

There is need for additional work on American petroleum oils in order that the tables in Circular No. 57 may be extended to cover a

wider range of density and temperature. Sufficient oil samples are on hand to continue this work, but at present the large amount of routine testing makes it impossible to devote a great amount of time to research without falling seriously behind in the routine testing.

Many requests were received during the year for the density and pounds per gallon of various vegetable and other oils. A publication giving these data would be very useful. The preparation of such a publication will require the determination of the density of representative samples of these materials. This work will be carried on as opportunity permits.

Testing.

The following is a report of the testing done by the volumetric section for the year ended June 30, 1921:

Apparatus.	Number submitted.	Number tested.	Per cent of total tested.	Number passed.	Per cent of total passed.
Burettes	1,323	820	62	566	43
Cylindrical graduates	378	308	82	72	19
Cone graduates	3	2	67	1	33
Dilution pipettes	1,501	1,477	98	1,273	85
Flasks	3,734	3,056	81	2,790	74
Pipettes, transfer	3,202	2,163	68	1,541	48
Pipettes, measuring	201	98	49	90	45
	10,342	7,924	77	6,333	61
Hydrometers	628	619	99	427	68
Capacity measures, including Dover and Seraphin measuring cans		161			
Density determinations		55			
Special apparatus:					
Picnometers		11			
Calibrating bulbs		49			
Flask standards		11			
Specific gravity flasks		11			
Miscelaneous		145			

An examination of the above data shows that of the volumetric apparatus submitted for test 77 per cent was eligible for test, 23 per cent being rejected upon preliminary examination. The major portion of the rejections in the case of flasks was due to unsatisfactory blanks having striæ and bubbles and to lack of stability due to improper design. Burettes in a few cases in which large shipments were made were very unsatisfactory as to workmanship, and a large number of leaky stopcocks were found during the year.

Sixty-one per cent of the glassware submitted passed the test, and of that actually tested 80 per cent passed the test. This is better by 2 per cent than the record of the previous year.

Of the hydrometers submitted 68 per cent passed the test, 1 per cent was rejected on preliminary examination, and the remaining 31 per cent had errors in excess of the tolerance allowed. In these cases reports were issued showing the errors found, thus making it possible to secure accurate results with these hydrometers by applying the corrections.

A comparison of the data given in this report with those given last year shows that there was an increase of 54 per cent in the number of pieces of glass volumetric apparatus submitted for test and of 47 per cent in the number of pieces that passed the test.

The number of hydrometers submitted shows a loss of 8 per cent. This decrease is accounted for by the fact that the Bureau of Internal Revenue no longer submits alcoholometers for test.

There were 502 Bureau of Standards numbers assigned to hydrometers. This is an increase of 15 per cent over the previous year. The time required to test hydrometers is materially increased when such numbers are assigned. Also, the instruments tested during the year were mainly on small orders and were usually of different ranges and types. It is gratifying to know that the trade is coming to appreciate the value of certified instruments.

The apparatus on hand awaiting test includes 811 flasks, 677 burettes and measuring pipettes, 1,356 transfer pipettes, 297 cylindrical graduates, 6 specific-gravity flasks, and 8 special pieces, a total of 3,155 against a total of 2,451 a year ago. With our present force and equipment it will require 8 to 10 weeks to complete the testing and forwarding of the stock on hand. There are also on hand a few hydrometers, dilution pipettes, and capacity measures.

Visitors.

There was an unusually large number of visitors, representing various firms who make glassware. They came in the interest of improving precision apparatus, and, judging from the subsequent improvements made in the quality of apparatus sent for test, they received information very useful to them.

A very great service can be rendered the makers of apparatus through conferences with their representatives at the Bureau. This institution is likewise benefited by these visitors, especially if they go away feeling that the Bureau has the desire, the equipment, and the personnel to help them in their work.

Additional Space Needed.

If the glass volumetric apparatus submitted continues to increase more laboratory room will be necessary. There is at present sufficient help for the laboratory space allotted to this section.

GAS MEASUREMENT.

Field Work.

Sixty-seven meters were tested for the Fort Worth Gas Co., Fort Worth, Tex., and a member of the gas measurement section observed and supervised the test of about 40 additional consumers' meters. This work was done in the settlement of a controversy between the gas company and the city of Fort Worth.

During the month of June, 1921, two members of the gas section were engaged in an extended test of so-called town border meters for the Lone Star Gas Co., Dallas, Tex. This work is still in progress, and a complete report can not, therefore, be rendered, at this time. Judging, however, from the work so far done and from the results of a similar investigation carried out about two and a half years ago, it appears that a very great saving may be effected by the location and stoppage of leaks between the town border and cousumers' meters. The former investigation showed an annual loss of natural gas amounting to some $4,000,000.

A member of the section has spent several weeks during the year at Trenton, N. J., in testing meters and related equipment for use of the Chemistry Division of the Bureau in carrying on a cooperative investigation of methods for the generation of hydrogen.

Research and Preparation of Tables.

The section has assisted the cement section of the Bureau in designing apparatus for measuring the volume of air supplied to an air separator used in grading fine particles of Portland cement.

An investigation was made of the differences of calibration of wet and dry meters with different gases. No consistent differences attributable to the use of different gases were observed.

Attention has been given to the calculation of tables of equivalent pressures and volume-reduction factors for use in meter testing. Also, some measurements have been made to determine the temperature differences between meter and meter prover under various conditions of test.

Routine Testing of Gas Meters.

Twenty-one meters of various types were tested in the laboratory during the year. This service was performed for departments of the United States Government, the Philippine Government, public service commissions, and private corporations.

EXPANSIVITY OF SOLIDS.

Research, Investigation, and Tests.

Data have been taken on all important terra cottas now being used throughout the United States. Similar data have been secured on underslips and glazes. This work is now ready for coordination and publication and will furnish valuable information for the terra-cotta manufacturers in their attempt to improve this material. In carrying on this work the Bureau was assisted by cooperation from the American Terra Cotta Society.

Results of tests on enamels made for the Ceramic Division are being tried out on a commercial scale at different enameling plants. The preliminary reports are encouraging and justify the conclusions previously reported that "fish scaling" of enamel ware is largely influenced by the relative expansions of enamels and stock. An abstract of this research will appear in the August issue of the Journal of the American Ceramic Society. This is to be followed by a Bureau publication.

The work being done on a series of 20 machine-gun steels has been completed. All specimens were carried above the transformation points and numerous observations taken during the passage through these points. This information is now being prepared for publication. This is, perhaps, the first work of this accuracy which extends over a temperature range from room temperature to 925° C. In addition to these special steels there have been examined a number of ordinary steels and irons, and this combined information will give a rather comprehensive paper on the subject. In all there were 244 expansivity tests made during the year.

The demand for a steel of low expansion has been great and is increasing, and the Bureau has been able to secure the cooperation of one of the steel manufacturers in producing this material. Some specimens have been produced which have lower expansion than much of the so-called invar. An attempt is now being made to get similar cooperation in the production of "elinvar" or some similar alloy of constant elasticity, a supply of which would greatly benefit certain industries.

The Bureau's report on the physical properties of dental amalgams has been well received by the societies and profession. Many inquiries and personal visits are being received concerning assistance on this and other phases of dental procedure. Preparations are being made to carry out a similar investigation on the properties of inlays and inlay investment materials. These researches are appropriate because of the number of defective restorations that are being put in by conscientious men.

Travel.

A representative of the Bureau was invited to address several dental societies and report on the Bureau's investigation of the physical properties of dental amalgams. The profession is very appreciative of this work.

Improvement of Equipment.

The equipment for thermal expansion has been improved decidedly by the addition of a platinum-rhodium gold thermocouple, a selecting switch free from thermal electromotive force, and lead-sheathed cables for potentiometer leads.

Work has been started on the problem of cutting precision screws. There are demands for line length standards with smaller errors than those now in use, and foreign laboratories have not been able to reduce the limit of errors in these supplies. A screw of higher precision is likewise in demand and could be used in ruling gratings. The findings to date demonstrate the necessity of securing or treating steel for permanence of dimension. The errors of gears and other periodic errors are readily detected and means are being provided for their elimination. This problem will of necessity continue over an extended period, since it is desirable to work out details relating to bearings, gears, lapping, ways, carriage, lines, etc.

The gauge section was requested to make up some polished steel surfaces for the line-ruling experiments. After making several attempts they were highly successful in producing hardened steel surfaces of a polish such that no scratches or defects were discernible with magnifications of 2,500 diameters. These surfaces have made it possible to develop the desirable characteristics of lines until lines considerably narrower than 1 micron can now be cut, the entire set of lines being highly uniform in width and shape of cut.

Some of the rulings were electroplated with nickel by the Chemistry Division and exact replicas were secured. In fact, no defects are discernible when using the highest magnifications. A further observation indicated that these nickel surfaces which have been electroplated to steel are of higher polish than it is possible to secure when polishing nickel directly.

COMMERCIAL SCALES.

Investigation of Railroad Track Scales.

The railroad track scale-testing equipments Nos. 1 and 2 of the Bureau of Standards consist of box cars carrying 90,000 pounds of standard weights in 10,000-pound, 2,500-pound, and 50-pound units, together with a truck weighing 5,000 pounds, upon which the weights can be loaded, equipped with an electric motor, so that it can be moved across the scale platform during a test. The test car is equipped with a gasoline engine, a dynamo, an electric crane, and other machinery and equipment for the unloading and loading of the truck and weights. Test car No. 1 has been in hard service since 1913 and No. 2 since 1915. At the beginning of the year it was found that equipment No. 1 would require very considerable repairs to the car body and equipment and replacements of worn out parts if it were to be kept in service, and equipment No. 2 was also badly in need of overhauling. Therefore during this year both cars have been laid up from time to time, and this work has been done partly by the personnel operating the cars and partly in railroad shops under the supervision of the Bureau's field force. This has necessarily resulted in considerable interruption to the testing schedule and unusually heavy expense connected with the work. In fact, during the latter part of the fiscal year lack of funds rendered necessary the laying up of the equipments during a large portion of the time. The master-scale schedule for the fiscal year 1921 which normally would have been completed during the calendar year 1920 was not completed until June, 1921, and the new schedule will be arranged to start in July of this year when funds will again be available. Both of the equipments mentioned above are now in good mechanical condition, and they can doubtless be kept in efficient service for some years to come.

During the year tests were made in 24 States and the District of Columbia, as follows: Arizona, California, Colorado, Connecticut, District of Columbia, Kansas, Illinois, Indiana, Iowa, Maryland, Massachusetts, Minnesota, Nebraska, Nevada, New Hampshire, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Rhode Island, South Carolina, Utah, Virginia, and Wisconsin.

A résumé of the tests made, except master-scale tests, is given in the following table:

Scales tested.	Number.	Correct.		Incorrect.	
		Number.	Per cent.	Number.	Per cent.
Railroad-owned track scales	245	132	53.9	113	46.1
Industry-owned track scales	29	17	58.6	12	41.4
Government-owned track scales	8	1	12.5	7	87.5
Total	282	150	53.2	132	46.8

The same tolerance is allowed as in the past, namely, 0.2 per cent, or 200 pounds per 100,000 load, this tolerance also having been adopted by the American Railroad Association and recommended by it to its members. The percentage of correct railroad-owned scales, 53.9 per cent, is about 10 per cent higher than last year, and the per-

centage of correct industry-owned track scales, 58.6 per cent, is about 20 per cent higher than last year. The correctness of Government-owned track scales is still very low.

The errors of track scales found incorrect varied from 0.21 per cent to 3.8 per cent, the average numerical error being 0.6 per cent. This excludes the error on one scale, which was subject to such deflection of parts under a 90,000-pound sectional load that the bridge rested on one of the levers, resulting in an error of 33 per cent.

Testing and Calibration of Master Scales.

For some years prior to the war and since the railways were turned back to private control the Bureau has had an agreement with the American Railway Association by the terms of which the Bureau maintains the standard of weight on the various lines of the country by testing all master scales once in each year and by making adjustments when needed and when by this means they can be brought within the established tolerances. The Bureau is convinced that this service is very necessary if the condition of the track scales in general use is to be maintained and improved, since these master scales are used in calibrating the test cars owned and operated by many of the railroads for testing their weighing equipment. Were the master scale to be incorrect, its error would be transmitted through the test cars to all the commercial scales tested and adjusted by them. The Bureau's equipments 1 and 2 are especially suited to the test of master scales, since they bring to these scales a sufficient amount of standard weights of known accuracy. No other equipments in the United States are suitable for such service. While traveling on the prearranged master-scale schedules the Bureau's equipments are moved by the various railroads free of charge. The agreement contemplates that the master scales will be tested once in each year, but this year, on account of delays previously described, the schedule intended to be completed December 31, 1920, was not finished until June, 1921. The master scales are located in various States, from North Carolina and Pennsylvania in the East to California in the West, and thus a very great amount of territory must be covered each year. Fourteen master scales owned by railroads, industries, and one State were tested.

The Bureau is pleased to report that new master scales have recently been installed and others are about to be installed, some being at new points and others are replacing some of those which have been reported by the Bureau in the past as unsatisfactory scales for the purpose.

Bureau of Standards' Master-Track Scale.

In 1916 the Bureau entered into a contract with a manufacturer to build a master-track scale for the Bureau, such a scale being even then urgently needed. The scale was built according to an advanced design which the Bureau and the manufacturer jointly developed, and it is probably the best master scale which has been constructed up to this time. The scale was completed several years ago, but unfortunately up to the present time funds have not been available for providing a centrally located test depot in which to house this scale. As a result the Bureau has been unable to realize upon its investment, although the scale is very urgently needed in the cur-

rent track-scale work, and without it this work must always be very greatly hampered. Track-scale testing equipment No. 3 comprises test cars Nos. 3 and 4, these being 40,000 and 80,000 pound self-contained test units traveling on their own wheels. Therefore they must be reweighted at intervals not exceeding two months in order to maintain and assure their accuracy, and this reweighing should be done on a scale operated and guaranteed by the Bureau. The 200,000 pounds of test weights (including the special trucks) carried on cars Nos. 1 and 2, which are used in certifying to the accuracy of every master scale in the United States, must be repainted and adjusted from time to time and the equipments overhauled. The Bureau has no present facilities for doing work of this character.

As pointed out last year, in addition to the needs of the Bureau the proposed testing station would also be used for the standardization of the test cars of all railroads entering the city in which the scale is located, the calibration of weights carried thereon, as well as the calibration of all heavy weights submitted for test by industries or railroads located in the vicinity. The maintenance of a Government-owned master scale and testing depot at some central point would do more, perhaps, than any other thing to furnish a correct standard of weight to be transferred to railroad-owned and industrial scales, to quicken the appreciation of accurate weights and weighing, and to reduce claims, allay suspicions, and provide a more stable basis for all business carried on by weight.

In the opinion of the Bureau, the city of Chicago is the most favorable location in the country for the station, as it would serve a maximum number of railroads and industries.

Mine-Scale Investigation.

The investigation of the condition of mine scales, used to determine the weight of the coal mined by the individual miners, and thus to ascertain the wages of the workers, was prosecuted as actively as was found possible. Experience in the past having demonstrated that it was impractical to attempt to operate the Bureau's equipments continuously throughout the year on the funds provided, it was decided this year not to attempt to operate both track-scale equipments and mine-scale equipments at the same time, since by so doing too large a field force would have to be employed. Consequently, as the need arose field men from the railroad-scale force were transferred to the mine-scale work, which latter was not actively prosecuted until spring. As a result excessive turnovers in personnel were avoided, and it was not required to train men in the work with the probable necessity of dispensing with their services after a short period, and thus efficiency was promoted.

The mine-scale work was carried on in fields not heretofore visited, Indiana and Illinois receiving special attention. A résumé of the scales tested is given in the following table:

	Number.	Per cent.
Total scales tested	231	.....
Correct	54	23.4
Incorrect	177	76.6

Magnitude of error in per cent.	Number.	Per cent of total incorrect.
0.5 to 1	75	42.4
1.1 to 5	90	50.8
5.1 to 10	9	5.1
Over 10	3	1.7
	177	100.0

The tolerance allowed on this class of scales is the same as that which has heretofore been permitted, namely, 0.4 per cent, or twice the tolerance allowed on railroad-track scales. The percentage of incorrect scales, 77 per cent, indicates the necessity for improvement of conditions, and this is emphasized by the size of the errors encountered, 57 per cent of the incorrect scales being in error by more than 1 per cent, and 7 per cent being in error by more than 5 per cent.

Good cooperation with the State officials in this work has been secured, and it seems certain that the inspections being made will have the effect of materially improving weighing conditions throughout the territories investigated. As in the past, it is found, in general, that the tests and results obtained therefrom do much to allay suspicion, quiet unrest, and increase industrial harmony.

Grain Scales.

Studies have continued on the results of tests and the detailed character of the errors of large scales, such as grain-hopper scales. These scales are used for weighing such large quantities of valuable commodities that their adjustment and maintenance is a matter of very serious importance. In this connection the Bureau responded to a request made by the State of Kansas and conducted a test upon a large grain-hopper scale, which was one of a number of scales of this type installed in that State, to enable the authorities having jurisdiction over them to determine whether or not they met certain specifications. This test was carried on up to a load of 120,000 pounds and is probably one of the most thorough and detailed ever carried out on a weighing mechanism of this character. Demands for high accuracy in these scales can consistently be met only by adjusting them with due regard to the character of their errors. Data in this work, however, accumulate slowly, as it is not often that the situation is such that the time required for making very detailed tests of the scales can be spared, since generally such tests require that the elevator cease operation. Railroads, States, and weighmaster's departments are cooperating with the Bureau in accumulating information on this subject. When the subject has reached a point where it can be regarded as a complete investigation, the results will be presented in the form of a publication available to all.

Quick-Weighing Scales.

Certain types of automatic dial scales are now in use in the freight depots on a large number of railroads and in other industries, and the subject of these scales received considerable study during the past year. It appears that these devices are of very great importance especially in facilitating the handling of freight where the movement

is heavy, as in New York City and Philadelphia, where a vast quantity of moderate-sized shipments is handled. These scales are often used where it is difficult or impossible to provide foundations which are desirable, and the exposure of these scales to continuous use, to vibration, and to conditions along water fronts, where moist air tends to corrode the scale parts, further complicates the problem. At the present time this form of scale is in very active development, and several new types are being tried out every year. The Bureau is furthering the progress in this subject to the fullest extent that its facilities permit.

Adjustment of Scales.

An important feature of the work in connection with the adjustment of scales has been the attempt to introduce more systematic and scientific procedure and to substitute for rule-of-thumb methods practices based upon sound principles of physics and engineering. To facilitate development along this line, a graphical computation chart has been prepared which permits certain values required in making the adjustments to be derived with the aid of a pencil and a straightedge in place of using formulas requiring arithmetical processes for solution. It is hoped that this will render it possible for many practical men to follow scientific principles in the adjustment of scales.

COOPERATION WITH STATES AND OTHER INTERESTS IN WEIGHTS AND MEASURES ADMINISTRATION.

Cooperation with States.

Cooperation with the States in matters pertaining to the securing of uniformity in weights and measures laws, rules, and regulations and the enforcement thereof, and uniformity of specifications and tolerances and the method of test of apparatus, thereby assisting in obtaining a greater degree of efficiency in weights and measures work throughout the country, has been continued during the past year. In pursuance of this work representatives of the Bureau attended State conferences of weights and measures officials in the States of Maine, Massachusetts, Michigan, New Jersey, New York, and Pennsylvania. In California a series of three district conferences and schools of instruction were held, and a representative of the Bureau attended these and by this means was brought into direct contact with practically every State and local official in the State engaged in the enforcement of weights and measures laws. In connection with this trip the officials of Oregon, Washington, Idaho, Utah, and South Dakota were also visited and a closer cooperation with these officials secured. This section of the country had not been visited for a number of years, and, inasmuch as only a limited number of delegates from these States are able to attend the annual conference, the information which was disseminated and secured was of particular value.

The Bureau also carries on this work by correspondence with the various officials, and since a large amount of information is available in the files of the Bureau much good is being accomplished in the uniform solution of problems common to many of the States.

Inspections, tests, and investigations upon various types of weighing and measuring devices were made in the laboratories of the Bureau to determine whether the apparatus submitted was accurate and whether it complied with specifications applicable to it. Special attention was given to liquid-measuring devices and devices intended to be attached thereto and used in connection therewith. Many new types are now being put upon the market and are of especial and timely interest to those enforcing weights and measures laws. Since the majority of the State and local departments do not have laboratory facilities for carrying out investigations, the data thus obtained are of great importance and assistance to them in their work. Reports are always sumbitted to the manufacturers of the devices and assist them greatly by helping them to correct and improve their product. They are further benefited by this work because there is secured a degree of uniformity of enforcement of law which otherwise would not obtain. In general, the results are of direct benefit to all the people, since the laws are more competently enforced, and more reliable and accurate apparatus is constantly being put into use in commercial transactions.

Fourteenth Annual Conference on Weights and Measures.

On May 23–26, inclusive, was held the Fourteenth Annual Conference on Weights and Measures, a body composed of State and local officials engaged in the enforcement of weights and measures laws throughout the United States. The meeting was attended by officials from 27 States and the District of Columbia, 21 of these being officially represented by one or more State officials, one by an interested person especially appointed by the governor for this purpose, and five by local officials. Eleven States had both State and local representation, in all 106 officials being present. Fifty-nine representatives of manufacturers of weights and measures apparatus and 32 other visitors representing railroads, weighing and inspection bureaus, baking associations, other industries, and other Government departments registered.

Many problems relating to weights and measures were taken up and disposed of during the four-day meeting. Chief among these, perhaps, was the proper method for the sale of bread. Representatives of baking associations were especially invited to attend the conference. Papers were read, followed by a full discussion. The result was the recommendation to the various States for adoption of a model bread bill based upon the principle of standardization of the weight of the loaves. Many of the States now have under consideration legislation relating to bread, and the action of the conference at this time will undoubtedly do much to secure uniformity in the enactments on this subject. The specifications and tolerances for liquid-measuring devices adopted last year were again subjected to scrutiny, and some few changes which experience had indicated as desirable were made. Interstate weighing, testing of mine scales and the weighing of coal, general enforcement of law, testing of commercial devices, and legislation also received attention. It is believed that the conference was among the most successful, helpful, and constructive of those thus far held.

New Legislation.

During the year just passed Congress has not enacted any new general weights and measures legislation, although a number of bills were introduced, received the attention of committees, and in several cases were passed by the House. However, Congress did place on the statute books a new weights and measures law for the District of Columbia which is a very much better act than the one which it superseded. This legislation was based in many particulars upon the model law recommended by the Bureau and, among other things, it abolished the fee system of inspection, a system which this Bureau has always strenuously opposed as being unfair, inequitable, and not productive of efficiency, and adopted the principle of the sale of bread in standard-weight loaves. The State of Illinois also passed a general act, excellent in most particulars and based on the model law. This act takes the place of a number of acts, many of which were obsolete and ineffective. Wyoming also passed a general law regulating commercial weights and measures, while Massachusetts, Minnesota, Nebraska, New Jersey, Ohio, Pennsylvania, and South Dakota, among others, made improvements in their present codes. In the South, Alabama, Georgia, and Kentucky enacted legislation particularly relating to the weight and measure of goods in package form.

Compilation of Weights and Measures Laws.

In the last annual report it was stated that the new compilation of State and National Laws Concerning the Weights and Measures of the United States was about ready for press. However, on account of the lack of funds it has not been possible to have this work printed. Since the compilation was made ready for the printer last fall several new State codes and compilations of State laws have been issued. These, as well as the recent session laws, have been examined and the manuscript compilation has been kept well up to date.

It is very much regretted that it was found impossible to publish this work, as there is a large demand for such information. Its early publication would be of great value to the Bureau in assisting the States and local authorities in weights and measures matters. State and local weights and measures officials would also profit by it in the prosecution of their work, as well as maunfacturers and commercial interests, as it would inform them of and enable them to comply with the various weights and measures laws affecting their products.

Cooperation with Other Government Departments.

Other departments of the Government have freely consulted the Bureau respecting scales and weighing. In several instances it was found possible to avoid the supposed necessity for the development and construction of new devices to meet special needs by employing devices already available on the market which were entirely satisfactory. Many tests of scales have also been made, especially for the War and Navy Departments. The Treasury Department, through the Director of the Mint, requested the Bureau to make an investigation of the automatic coin scales used at the mint in Philadelphia in the weighing of all coins produced there to determine the reason

for discrepancies that had been observed in the weights of coins. A special method of test was devised and applied, which very clearly demonstrated the performance under service conditions of each of the 80 beams employed and indicated what errors were to be expected in their use. The maintenance of the standard weights of the various coins within the tolerance prescribed by law is a matter of extreme importance, and the Bureau is very glad to utilize its personnel and facilities in the solution of such problems.

Cooperation with Outside Interests.

During the year the Bureau has also cooperated with many States, manufacturers, railroads, and other agencies on matters of general importance in connection with weighing. The Bureau has continued to work both with the manufacturers of and those using scales in developing specifications for various types of weighing devices, the object being to assist in obtaining scales constructed in conformity with correct and definitely established engineering principles, to effect economy in manufacture, with a consequent reduction in price, by the elimination of types which are unnecessary and which can be dispensed with without any practical disadvantages, and to insure specifications of such a character that those requiring scales for certain purposes will secure scales best adapted to their needs. In furthering this work special studies have been made to determine the actual conditions under which scales are used, since information of this character is very necessary if practical results are to be secured.

Papers on scales and weighing were given before various organizations, such as the Farmers' National Grain Dealers' Association, the National Scale Men's Association, the Weighmasters' and Scale Men's Conference. The observance of specifications for scales which had been prepared in connection with loss and damage claims in a case before the Interstate Commerce Commission, and in which this Bureau had cooperated with other interests in drawing up specifications designed to improve scales, was advised, to the end that the question of uncertainty in weights in loss and damage claims would be reduced to the minimum.

GAUGE SECTION.

Research and Design.

Methods of measuring plain ring gauges have been examined, and the conclusion has been reached that the determination of the internal diameter of the ring gauge can be accurately made by means of two balls, the sum of whose diameters is slightly greater than the nominal diameter of the ring. When two balls of these dimensions are placed in the ring, resting on a surface plate, it is only necessary to measure the difference in height of the tops of the balls to secure sufficient data to compute the diameter of the ring. Steel balls can be obtained that are round to one or two hundred thousandths of an inch. An apparatus has been designed and built for conveniently and accurately measuring the difference in height of two balls placed in a ring resting on a surface plate.

Some time has been spent in measuring experimentally the dimensions of gears with balls, cylinders, and gauge blocks on the sur-

face plate, and a method of determining the pressure angle of a gear at any point has been developed using these gauges. Additional data have been secured which will assist in the design of a gear-testing machine.

A device for testing an extensometer, designed to measure the compression in the piston rod of the recoil mechanism of large guns, has been designed and successfully used in the test of the extensometer.

A device employing an indicator was designed and built to measure the variation in diameter of the bore of rifle barrels. This device was used successfully in determining the variation in diameter of used rifle barrels submitted for examination by the War Department.

Improvements in detail have been made in the optical projection lantern used in projecting images of profile and screw-thread gauges. This instrument is now provided with a micrometer screw accurate to 0.00002 inch. Changes have been made in the carriages for holding gauges so that larger gauges can be measured and long screws, such as lead screws of lathes, can be examined. One of the Bureau's lead testers or instruments for measuring pitch or lead of screws and screw gauges has been adapted to measure both the larger gauges and longer screws, such as lathe lead screws. This enlarged machine has been successfully used to measure the lead or pitch of large-size pipe-thread gauges and also medium-size gear-cutting hobs. The instrument could be redesigned to advantage to provide a much heavier and more rigid machine for the convenient and accurate measurement of large-size gear-cutting hobs.

An adjustable thread-plug gauge has been designed and built in the shop for determining the pitch diameter of tapped holes. The need for this instrument was felt in connection with investigational work requested by the National Screw Thread Commission.

Some time has been devoted to the problem of producing optical flats in quantities by mechanical means. The method employed is an adaptation of the method used in lapping precision gauge blocks and gives promise of ultimate success.

Several types of gauges were designed and made to gauge pearl buttons. These gauges have been submitted to the pearl-button manufacturers for criticism and some comments have been received which will aid the Bureau in designing more useful types of gauges for the industry.

Testing of Gears and Gear-Cutting Tools.

Great strides have been made in the last few years in the methods of cutting gears. However, there is a constant demand on the part of the users of gears for a more perfect article and a continual striving on the part of the manufacturers of gears to satisfy this demand. Since the nearness of approach to correct tooth outline and accurate spacing of teeth determines the efficiency, length of wear, and amount of noise when running, there has been an ever-increasing demand for greater accuracy in gears. In some methods of cuttting gears the greatest opportunity for advancement appears to lie along the line of careful inspection and of improvement in the accuracy of tools and machines used in cutting the gears. This inspection must necessarily be coupled with a similar inspection of finished gears. These remarks apply particularly to the manufacture of gears by

the hobbing method. During the past year the Bureau has made a special test of hobs for one manufacturer and has been requested to test in the near future hobs made on a hob-grinding machine recently designed by another. This latter concern is building the machine at a considerable expense, because it is claimed that the hobs supplied by regular hob manufacturers are not sufficiently accurate. The lantern and lead tester used in the inspection of thread gauges are useful in measuring some of the dimensions of gears and gear-cutting tools. There has been loaned to the Bureau by the Pratt & Whitney Co. a Saurer gear-testing machine which indicates variations in the velocity ratio of a pair of spur gears. An attachment has been designed for this machine to indicate variations in the velocity ratio of a worm and worm wheel. This attachment is practically completed and will be tried out shortly to complete the test of a worm wheel for a motor truck. There is great need for a gear-testing machine employing the best practice now in use in the testing of gears and gear cutters. The design and manufacture of such a machine will be undertaken during the coming year.

Routine Testing of Gauges.

The number of lots and the number of gauges and other articles requiring contact measurement submitted month by month are shown in the following table:

Month.	Number of lots.	Number of gauges.	Month.	Number of lots.	Number of gauges.
July, 1920	8	130	February	15	[1] 883
August	17	111	March	14	588
September	16	227	April	15	280
October	14	429	May	14	340
November	17	269	June	18	83
December	10	315			
January, 1921	17	522	Total	175	4,177

[1] This includes 766 polariscope tubes submitted by the Treasury Department.

Of the above gauges, about 27 per cent were submitted by the Government departments other than the Bureau of Standards, about 3 per cent by the Bureau of Standards, and 70 per cent by private concerns. During the preceding year 76 per cent of the gauges tested were submitted by Government departments other than the Bureau of Standards, and only 17 per cent by private concerns. The total number of gauges submitted shows a slight increase over the preceding year, when 3,911 gauges were submitted. The great decrease in the number of gauges submitted by the Government departments is due to the reduction in the manufacture of munitions and munition gauges by and for the Government. It should be noted that this decrease is practically counterbalanced by the increase in the number of gauges submitted by private concerns intended for use in the manufacture of commercial products.

Testing of Gauges for Commercial Concerns.

There is a continual tendency on the part of manufacturers to improve the quality of their product by the reduction of tolerance on parts intended to interchange. This reduction in tolerance must

asually be coupled with a reduction in the tolerance on the gauges required to inspect the work. The diminished tolerance on the gauges increases the difficulty of determining whether a particular gauge is within the tolerance specified. Usually the gauge user is not equipped to inspect all types of gauges with sufficient accuracy to determine whether they are within the tolerance specified, and frequently the gauge manufacturer is not equipped with proper instruments and apparatus to make the measurements. It is in such cases that the Bureau is called upon to act as a referee to determine whether the gauges should be accepted or rejected.

Judging from the class and variety of work submitted to the Bureau by manufacturers during the past year, there is a tendency to require careful inspection of certain gauges and tools which formerly the user accepted from the manufacturer without any question as to accuracy. For example, this tendency has been noted in regard to plain ring gauges and hobs for gears. In the first case certain users of ring gauges are no longer satisfied with a mere statement that a standard plug gauge will enter the ring, as it is realized that a ring gauge can be subjected to a large and variable force tending to expand the ring when the plug is entered in the usual way. In regard to hobs for gears, manufacturers of gears by the hobbing process have felt the effects of keen competition with gears made by other processes, especially ground gears, and in attempting to improve the quality of their product they are inclined to require a rigid inspection of the hobs used.

Finger-Ring Gauges.

A wide divergence has been noted in the dimensions of finger rings and ring gauges of the same nominal size. The method of use of the gauges also varies. This tends to increase the difference between rings and gauges intended to be of the same size. The Bureau has been unable to find any list of universal standard dimensions, each manufacturer of both rings and gauges appearing to follow his own ideas as to what dimensions are proper. A preliminary schedule of dimensions has been drawn up and will soon be submitted to the trade for consideration.

Shopwork.

In addition to instruments and devices designed in the laboratory, of which mention has been made above, the shop has completed 5 projection lanterns, and 12 sets of adjustable parallels for the Ordnance Department and has built 1 lantern for the use of the gauge section. Considerable work has been done in building regulating apparatus and equipping the constant-temperature room.

Travel.

A member of the Bureau attended meetings of the American Society of Mechanical Engineers Committee on Plain-Limit Gauges and meetings of the National Screw Thread Commission. Also, a trip was taken to Providence, R. I., to testify in a suit involving a manufacturer of munition gauges. Testimony was given as to the methods employed in testing gauges and as to the accuracy of a lot of gauges tested by this section. Two members of the staff visited

several manufacturers of gears and gear-cutting tools, and much valuable information was obtained as to the requirements of manufacturers and the methods of testing gears. A visit was also made to several manufacturers of pearl and composition buttons and first-hand information obtained with regard to the problems and requirements of this industry.

National Screw Thread Commission.

A very considerable amount of work has been done by members of the division in connection with the National Screw Thread Commission in its work on standardization of screw threads. This work is especially important in the field of interchangeable manufacture of machine products. A progress report has been issued which has been very well received by engineers and by the mechanical industries and which marks a notable advance in screw-thread standardization. A program has been outlined for continuing the work, and it is felt that this will result in still further progress.

American Society of Mechanical Engineers' Sectional Committee on Unification and Standardization of Screw Threads.

The Bureau is represented by membership on the above committee, one of the objects of which is to pass upon the progress report of the National Screw Thread Commission, with a view to its recommendation to the American Engineering Standards Committee for adoption as an "American standard" as defined by that organization.

American Society of Mechanical Engineers' Sectional Committee on Plain Limit Gauges for General Engineering Work.

The Bureau is cooperating with the above committee, the purpose of which is to set up standards of practice in the manufacture and inspection of machine products, with a view to securing economy of production and efficiency of operation of these products. This work is well under way, and it is hoped that a comprehensive report can soon be issued which will aid materially in putting the design, construction, and inspection of machine fits on the sound basis of the best engineering practice.

Standardization of Buttons.

A representative visited the headquarters of the fresh-water pearl-button industry in Wisconsin and Iowa to obtain information as to the need and possibility of standardization in that industry. Much valuable information on the methods of manufacture and inspection was obtained, and it is believed that the Bureau can aid materially in drawing up and putting into use definite standards of measurement and quality of pearl buttons. The work of establishing standard dimensions is already well under way and is being carried forward by a committee of the manufacturers.

The establishment of standards of quality will be more difficult, as any classification as to grade or quality is necessarily based upon the judgment of some individual or group of individuals. Some progress, however, has been made, and most of the manufacturers are hopeful of arriving at a reasonable degree of uniformity of quality as well as uniformity of dimensions.

A visit was also paid to the manufacturers of composition buttons at Auburn, N. Y., for the purpose of comparing the problems of the two industries. It was found that the problems of manufacture and standardization in the two industries are entirely different and should therefore be considered separately.

PUBLICATIONS.

The following publications and information in mimeographed form relating to the work of this division have been issued during the year.

Progress Report of National Screw Thread Commission.

The National Screw Thread Commission, authorized by an act of Congress approved July 18, 1918, completed its preliminary work of standardization and issued a progress report covering the work done. This report, published as Miscellaneous Publication of the Bureau of Standards, No. 42, contains very comprehensive specifications and tolerances for screw threads and much valuable information on screw thread gauges and methods of gauging.

Jewelers' and Silversmiths' Circular.

A new circular, No. 43, Jewelers' and Silversmiths' Weights and Measures, which covers a variety of subjects of interest to jewelers and workers in precious metals, was issued and will serve as a valuable handbook for the trade.

Thermal Expansion of Copper and Its Alloys.

Data on the thermal expansion of 128 samples of copper and its important alloys of various compositions, heat treatments, and mechanical treatments are given in Scientific Paper 410. Most of the samples were examined from room temperature to about 300° C., several specimens being cooled to —50° C. and then heated to +300° C.

Report of Annual Conference.

The report of the Annual Conference on Weights and Measures was published, as usual.

Screw-Thread Pitches.

A paper has been prepared for publication in which a graphical method has been used to convert screw-thread pitches from English to metric units, and vice versa.

Thermal Expansion of Metals.

A publication is now in press on the Thermal Expansion of Nickel, Monel Metal, Stellite, Stainless Steel, and Aluminum.

Testing of Large Capacity Scales.

During the year there was prepared for publication Technologic Paper 199, Method for the Precision Test of Large Capacity Scales. This is a description and explanation of the method developed by the Bureau of Standards for the precision test of scales, such as railroad master scales and large grain hopper scales. However, the plan out-

lined can be adapted easily to the test of almost any weighing device, and the publication, it is felt, will be valuable as a reference text for most engineering laboratories where the need arises now and then for the test of weighing mechanisms with more than ordinary precision.

Technical Data and Information.

The following technical data and information were prepared, in mimeograph form, for distribution: Table of equivalents of United States gallons in terms of British imperial gallons, and vice versa. These tables will also apply to other units of the same relative sizes, such as United States quarts to British imperial quarts. Table of equivalents of cubic feet in terms of cubic meters, and vice versa. Weights of a cubic foot of limestone. This paper includes a discussion of the voidage or vacant spaces between the particles of sand, gravel, and broken stones, and the weight of a cubic foot of broken limestone and its dependence upon the specific gravity of the solid material and the percentage of voids.

2. ELECTRICITY.

The work of this division covers electrical units, standards, measuring instruments, and methods of measurement, including electromotive force, resistance, current, inductance, capacitance, conductivity, insulation, magnetic measurements and properties, radioactivity, radiocommunication, and properties and performance of electrical equipment, such as lamps and batteries. As a result of cooperation with technical societies, testing laboratories, electrical industries, public service companies, public utility commissions, municipalities, and engineers in problems of standardization, including standards of adequacy and safety of service, some of the work has been extended to cover more than strictly electrical service.

GENERAL.

Scope of the Electrical Work.

One of the most important functions of the Bureau with respect to electricity and allied subjects is the establishment and maintenance of the fundamental standards upon which all electrical measurements are based, including cooperation with similar institutions in other countries so as to secure international uniformity. This includes the intercomparison of standards, extensive research in methods of measurement, and the development and improvement of subsidiary and derived standards. These standards are utilized and the results of the researches are applied in the testing of reference standards and instruments for manufacturers, testing laboratories, universities, research institutions, electric utilities, utility commissions, engineering and other interests, and various agencies of the Government.

The testing of electrical instruments and apparatus is of two main classes. First, there is the standardization of reference standards and precision instruments for manufacturing and other institutions which themselves make or standardize instruments for commercial use or which conduct research work. It is through the work of such institutions that the measurements made in practice are referred back to the standards of the Bureau. Second, a limited amount of testing of commercial electrical measuring instruments, radio and photometric apparatus, magnetic materials, etc., is done chiefly for the purpose of keeping the Bureau in touch with the needs of the industries, of developing methods, and of improving

apparatus and materials. The greater portion of this testing is done for the Government services and serves the double purpose of providing information to be used in formulating specifications and of determining the quality of materials furnished upon specifications.

The research work has mainly to do with methods of measurement, the determination of the electric and magnetic properties of materials, and the development of those phases of engineering science in which measurement plays an important rôle. In general, this investigational work deals with fundamental properties and principles, so that the results may be applicable to a class of problems rather than being limited to the one specific problem under investigation. The work on correlation of magnetic and mechanical properties of iron and steel and in the study of insulating materials are examples.

The research work in radiocommunication, magnetism, radioactivity, and photometry is along lines quite similar to that in the more purely electrical measurements. Standards have been and are being developed, methods of measurement are being improved, and important special problems of significance to the industries and in a number of cases of particular importance to the Government are being investigated. Specific examples of the projects in hand during the past year are given in the sections below.

Public Utility Investigations.

Another important activity of this division, including more of engineering and field work than most of the electrical work referred to above, is the investigation of problems arising in connection with various public utilities, particularly electric light and power, gas, street railway, and telephone services. The work includes (1) scientific and engineering research, (2) the study of the conditions which determine the quality of public utility service of various kinds, (3) methods of testing and inspection employed by municipalities and commissions, (4) safety rules for use by the utility companies to safeguard their employees and the public, and (5) the collection and distribution of information by published papers and through correspondence.

This work is a natural outgrowth of the research and testing done by the Bureau of Standards for the public utility companies and commissions. The testing of electrical instruments and meters, of gas lamps and the standards employed in measuring the candlepower and heating value of gas, the life testing of electric lamps, the testing of instruments used in telephone work, research on electrolysis mitigation, and similar investigations and tests connected with the public utilities, have all involved to a greater or less degree questions of standards of service. The Bureau has gradually accumulated a considerable amount of information on these questions and has been able to contribute materially to the establishment of standards of quality in several of these services. Furthermore, it has promoted with marked success the practice of settling disputed questions in this field on the basis of sound engineering and economic principles and of cooperation between interests rather than by legal controversy, and in so doing the Bureau has attained a recognized position as mediator in such questions.

In many States the public service commissions have set standards of service for the different utilities, and the Bureau has cooperated

with most of those that have done so. In other States these problems are dealt with more or less independently by the different municipalities. For most cities and many commissions it is a difficult matter to judge the quality of service rendered by the utilities. Obviously, it will never be economical or desirable for each State commission or city to handle these questions alone. Though they possess large and able engineering staffs or employ specialists for each separate problem, the question of what is good service or whether the service in any given case is adequate, safe, and satisfactory can usually be settled only by reference to what is done under similar circumstances elsewhere in the country. In other words, standards of good practice and good service are largely determined by general experience and should be studied comparatively, using the experience of the entire country. The Bureau has been doing this for several years, and although it has not been able to do as much as it would have liked it has done enough to demonstrate the practicability and acceptability of the method. It will conduce to fairness and a good understanding to have the subject studied further and to have specifications as definite and complete as possible made available for all branches of public utility service. The present status of the utility work is summarized in the sections following those on electrical measurements.

STANDARDS OF RESISTANCE.

Routine Testing.

The demand for the testing of resistance standards, Wheatstone bridges, potentiometers, and similar apparatus, and for the determination of the electrical properties of conductors has been greater than at any time during the history of the Bureau. Not all of the tests required could be taken care of, though more than half the resources of the section were devoted to this work.

International Comparison of Standards of Resistance.

During the year four of the Bureau's 1-ohm resistance standards of the type used in maintaining the unit were sent to the National Physical Laboratory of England for comparison with the English resistance standards, and two of the 1-ohm resistance standards belonging to the National Physical Laboratory were compared with the Bureau's standards. This intercomparison serves to show accurately what, if any, difference exists between the units of resistance used in the two countries. This is the first intercomparison of the kind made since before the war, and it is gratifying to find that the difference in units used is only a few thousandths per cent.

Refinements in Resistance Measurements.

In the use of Wheatstone bridges or potentiometers it is known that in case there is leakage from the leads supplying the test current and from the leads to the detecting instrument, or in case the test current is alternating and there is unbalanced capacity between these leads and "ground," highly accurate results can not be obtained unless certain precautions are taken. One of the means used for getting definite balances in such cases is to ground one of the leads to the detecting instrument. Investigation shows that this is bad practice, since, while it may enable the establishment of a

definite balance, the results are more likely to be in error than if the lead had not been grounded. The effectiveness of a ground on a branch in parallel with the source of current has been investigated and compared with the effectiveness of a ground on a branch in parallel with the detecting instrument. It is found that with reasonable care reliable measurements can be made when either device is used; that in some cases it is more convenient to use one and in other cases the other; and that there is but slight advantage in using both simultaneously.

Units of Resistance.

In England the suggestion has been made that the use of international electrical units be discontinued, and that all electrical units be made definitely a part of the C. G. S. system. The measurement of resistance in electromagnetic units—that is, in the so-called absolute units—has been given careful consideration. From time to time a number of possible methods of measurement have been devised and the relative advantages and disadvantages of these compared with the method proposed by the late Dr. Rosa, of this Bureau, the method used in the most recent and best work in the National Physical Laboratory, and with various other methods either proposed or which have been used. From this comparison a conclusion has been reached regarding the methods to be employed and the type of apparatus to be used as soon as funds are available for the construction of this apparatus. This problem involves, among other things, accurate control and measurement of the speed of rotation of the machine used, and considerable experimental as well as theoretical work has been done on this phase of the subject.

The Statement of the Conducting Quality of Conductors.

This is a matter concerning which there has been a considerable lack of uniformity and more or less difference of opinion. An investigation of the subject shows that several different procedures might be followed in establishing units of resistivity; that there is need for units established in two different ways; and that there is need for a convenient way of designating the units used in any particular case. It is believed that if two units could be adopted by international agreement and that if names could be assigned to these units, as has been done for many of the electrical and magnetic units, this particular branch of electrical measurements would soon be on a satisfactory basis and the names adopted have as definite significance as those of the other electrical and magnetic units.

Resistance of Human Body.

The investigation of the electrical resistance of the human body, reported upon last year, has been continued. New apparatus which gives greater refinement in the measurement has been constructed and additional measurements have been made. While the resistance, exclusive of the resistance through the skin and in the vicinity of the electrodes, is definite, as previously reported, the resistance of the same individual depends somewhat on the extent to which the muscles are tense or relaxed, and there is a cyclic change synchronous with respiration which is just noticeable with the improved apparatus.

Measurement on the same individual at different times shows variations much greater than the uncertainties in the measurements. A paper on this subject was presented at the April meeting of the American Physical Society, and the proceedings of this society will contain a fuller report on the work.

Electrical Method for the Measurement of the Rate of Natural Corrosion in Sheet Metal.

The electrical resistance of a definite portion of a sheet of metal depends, among other things, upon the thickness. If, therefore, reliable measurements could be made of the resistance from time to time, they might be made to serve as a means for determining the rate at which the thickness is decreasing as a result of natural corrosion. A method for making such measurements has been developed and tried out in the laboratory. Four point contacts are made on large sheets, and the resistance of the four terminal conductors thus formed is measured by a simple type of potentiometer. It was found that the measurements can be made rapidly and with sufficient accuracy for the purpose. The method is applicable to cases such as metal roofs, whether or not they are covered with a protecting coat, such as paint.

INDUCTANCE AND CAPACITANCE.

Inductance and Capacitance Laboratory.

The routine testing which is requested of this section now consumes a very large part of the time of those who are working on inductance and capacitance problems. Many of the tests can not be made in any other laboratory in this country. They are, in effect, research problems which are of great importance to manufacturing industries. In order to handle these tests promptly, an increase in personnel and laboratory facilities is necessary. A number of minor changes have been made in the method of conducting the more routine tests in order to expedite measurements and calculations. This has required the addition of a small amount of equipment, but the saving in time has been considerable.

Inductance Research.

As the laboratory facilities are so largely used for testing work, research work has been to a great extent confined to theoretical investigations. The integration method of deriving alternating-current resistance and inductance has been extended to a three-phase cable. An article on this subject is now in preparation. The same method has been applied to determine the alternating-current inductance and resistance of a coil of wire. This will also be published in the near future. By an entirely independent method a formula has been derived for determining the alternating-current resistance and inductance of parallel wires. This is applicable to a considerably larger range of frequencies than the formulas which have been previously published.

A small amount of experimental work has been done on measuring the inductance and resistance of parallel rods. This is needed in order to check the theoretical formulas which have been derived.

Also, some measurements have been made on the inductance and resistance of a specially constructed solenoid. The methods which were developed for this have been used in measuring the resistance and inductance of lightning-rod cables. This test was requested by a lightning-rod company in order to obtain more information concerning the properties of the materials which they are using.

Capacitance Research.

For several years a set of air condensers has been under observation in an attempt to learn the causes of changes in capacitance. Observations are still in progress. More active work on this problem will be undertaken as soon as facilities permit. A research was undertaken at the request of a manufacturer of electrical apparatus on some large paper condensers. The capacitance and phase difference of these condensers were measured at voltages ranging from 600 to 2,000 volts. Condensers of this type are now becoming of considerable importance.

BALLISTICS AND ALLIED PROBLEMS.

Cooperation with Navy Department.

Certain ballistic investigations which were started during the war and involved precision electrical and time measurements have been continued throughout the year at the request of the Navy Department. In addition some new problems have been undertaken, to the solution of which the facilities developed in connection with the ballistic work can be directly applied. The Bureau of Standards has been making the necessary precision measurements (largely electrical) and interpreting the results obtained, while the Navy Department has provided the facilities for conducting the experimental work. The specific investigations are as follows:

Study of the Variation of Gun Pressures with Time.

The electrical gauge for measuring pressures in guns as originally designed was given a thorough test during the ignition firings at Indianhead in July, 1920. Some very satisfactory curves were obtained showing the variation of pressure with time. However, during this firing some of the weak points of the gauge became apparent and a new type of gauge has been designed. This has been tested in a bomb, but has not yet been given a service test.

Primer Explosion Times.

A report on the results obtained by firing a large number of primers in the laboratory is now being prepared. This work has not been considered urgent and during a large part of the year has had to give way to more urgent problems.

Ejection Velocities.

Some improvements in the method of measuring ejection velocities on battleships have been made, but the results of experiments on the U. S. S. *Tennessee* indicate that still further modifications are necessary. There is every reason to believe that this method is capable of giving the required accuracy.

Firing-Time Intervals.

Measurements of the physical firing intervals and subintervals during the ignition firing at Indianhead have given results of unusual value. The time at which various events in the firing of the gun occur are now known.

Interior Ballistic Formulas.

In attempting to determine the pressure inside the bore of the gun from the acceleration of recoil, it was found that the ordinary ballistic formulas were not sufficiently accurate. It was therefore found necessary to develop a formula which takes into account the fact that the diameter of the powder chamber is different from that of the bore of the gun. These new formulas are contained in an appendix to the report on the ignition firing at Indianhead.

Pressure in Recoil Cylinders.

Two different types of pressure gauges have been constructed for obtaining the time-pressure curve in recoil cylinders. Also, an extensometer has been constructed by which it will be possible to measure the rate of extension of the piston rod of the recoil cylinder. These results are needed in order to check properly the ballistic formulas referred to above.

Velocity of the Projectile Inside the Bore of the Gun.

Apparatus has been constructed for determining the velocity of the projectile in the bore of the gun by means of the expansion of the gun barrel. This apparatus is now ready for trial.

Photography of Projectiles in Flight.

Some additional development work has been done on a camera for this purpose. A timing system has been installed which will permit measurements of the velocity of the projectile. While it has not been used throughout the year to photograph projectiles, yet it has been used to study the incorrect functioning of a machine gun, in which case it was necessary to take pictures at intervals of a few thousandths of a second.

"Sao Paulo" Report.

A report on the results of certain tests in connection with the firing on the Brazilian battleship *Sao Paulo* has been prepared and submitted to the Bureau of Ordnance, Navy Department. This report has been distributed by the Navy Department among officers of our Navy and to the Brazilian Government.

Measurements on the U. S. S. "Tennessee."

Representatives of the Bureau of Standards made measurements of the ejection velocities during the calibration trials on the U. S. S. *Tennessee*. Measurements were made of two 12-gun salvos, and in each 11 satisfactory velocities were obtained.

Measurements of the movements of the turrets were made during the structural test firing on the U. S. S. *Tennessee*. This work was done for the Bureau of Construction and Repair, Navy Department, and a report has been rendered to that Bureau.

Physical Constants for Submarine Mines.

At the request of the Bureau of Ordnance a study has been made of some of the fundamental physical constants of submarine mines. In order to make these of value considerable mathematical analysis has been necessary. A report on certain phases of this work has been submitted.

Design of Oscillographs.

The Bureau has used in its ballistic work the General Electric oscillograph with some modifications. These instruments were made for an entirely different purpose and were not quite suited for this work. At the request of the Bureau of Ordnance, Navy Department, a complete new design of the oscillograph was made, keeping in mind its use for ballistic investigations. Six oscillographs according to this new design are now being constructed by the General Electric Co. for the Navy Department.

Investigations of Turret Movements and Strains During Gunfire.

The Bureau of Construction and Repair, Navy Department, has requested this Bureau to make measurements during the firing of the U. S. S. *California* of the movements of the turrets as a function of time. Similar measurements will be made on the strains in the turret structures. In order to have satisfactory data from which apparatus for the above measurements may be designed, some preliminary measurements were made on the U. S. S. *Tennessee*. These measurements gave so much information concerning the behavior of the turrets that the Navy Department has requested the Bureau to make similar measurements on the U. S. S. *Maryland*.

A large part of the apparatus for conducting the work on the U. S. S. *California* has been designed and constructed. Methods of mounting this apparatus have been worked out in connection with the Navy Department, and the necessary brackets are now being installed on the U. S. S. *California* at the Mare Island Navy Yard. The investigation is a very elaborate one and will require at least another year for carrying out the experiments and completing the report.

Study of Soluble Washers.

A study has been made in connection with the action of soluble washers to be used as delay devices in submarine mines. One phase of the subject was carefully studied in the laboratory and a report thereon submitted to the Bureau of Ordnance, Navy Department.

ELECTRICAL MEASURING INSTRUMENTS.

Testing of Electrical Instruments.

The amount of testing was nearly as great as for the preceding year, in spite of reduced personnel. For this reason it has not been possible to devote as much time as ought to be given to the proper maintenance of the working standards used, the development of improved apparatus, and the extension of the range of testing.

Electrical Tests of Ignition Apparatus.

This work has been carried on in cooperation with the automotive section of the Division of Heat and Thermometry.

Two papers dealing with the mathematical theory of the production of voltage in the "high-tension" magneto have been completed. Experiments have been made on the breakdown voltage of spark gaps in which one electrode is heated. This simulates the conditions existing in the engine. Such gaps show a very marked decrease in the sparking voltage under this condition, even though the bulk of the gas in the gap is kept cool.

A very considerable amount of time has been occupied in replying to questions in correspondence bearing upon ignition.

Cooperation with National Associations.

The section has been represented on the following committees: Instruments and Measurements, American Institute of Electrical Engineers; Insulation, Engineering Division, National Research Council; Terminal Markings, Electric Power Club; Unbalance Factor, Standards Committee of American Institute of Electrical Engineers. A number of committee meetings were attended and a list of matters of terminology prepared for circulation among the members of the first-named committee with a view to securing ultimately an agreement on the best practice.

The section cooperated with the subcommittee on liquid insulation of Committee D–9, American Society for Testing Materials, by collecting and digesting the results of an extended series of measurements on various types of spark gaps for testing transformer oil. This work was begun before the war, was held in abeyance for several years, and has now been completed and will be published in the report of this committee to the society.

Cooperation with Manufacturers.

Visits were made to the factories of the principal makers of electrical instruments and meters in order to become familiar with their manufacturing methods and products and to determine how the Bureau could be of the most service to them. At the request of one maker a material was located which was superior to the one he had been using. Further investigation along this line is in progress. Manufacturers of electrical measuring instruments are dependent upon electrical standards of all kinds, and are greatly interested in the use and methods of testing of such apparatus. Hence, the Bureau endeavors to furnish the data necessary in keeping these instruments up to their high standard of excellence.

Development of New Apparatus.

The commercial application of high voltages has far outstripped the facilities for their measurement. The section began the design of an accurate instrument for such measurements in 1916, but the work was dropped at the beginning of the war. It has recently been resumed, with plans for a much larger instrument capable of measuring up to 250,000 volts, the highest voltage which is at present contemplated for power transmission. This work is of increasing importance, because at these high voltages the insulation is the determining factor in design of transmission lines, and failure of insulation entails costly damage to apparatus and expensive shutdowns of the industries served.

MAGNETIC MEASUREMENTS.

General Magnetic Measurements.

Most of the work in general magnetic measurements, aside from the usual amount of routine testing, has been done in connection with a study of methods for testing very short specimens. In many cases, especially for the study of very pure materials or of special alloys of which only a limited amount is available, it is important to be able to test rather small specimens. A number of possible methods are now under investigation, and it is hoped that it will be possible to work out a satisfactory solution of the problem.

Magnetic Analysis.

The purpose of magnetic analysis is to afford a knowledge of the quality of steel and steel products as regards freedom from flaws, strength, etc., without in any way injuring the piece. The general application of such a nondestructive method of testing would undoubtedly effect great savings of both material and labor, besides adding to safety in the use of steel products. The saving would be effected by the elimination of defective material before expensive manufacturing processes had been applied, and by making possible the use of all good material in a lot having such a quantity of unsatisfactory material that the whole shipment would otherwise be rejected.

There has been an increasing interest in the subject on the part of engineers and users of steel during the last few years, and many investigations are being carried on by industrial and educational institutions. These investigators naturally look to the Bureau for assistance in the development of testing methods and the collection of correlation data for use in interpreting the results of magnetic tests. The magnetic section has endeavored to meet this demand for information and cooperation as far as its limited funds would permit.

Thermomagnetic Analysis.—The apparatus for the detection and study of the transformations which take place in the structure of steel upon heating or cooling was partly completed during the year. This work has been practically at a standstill for some time, owing to the resignation of the physicist who was developing the method. However, some progress is being made in this investigation as opportunity permits. The completion of this apparatus should afford a means of obtaining much valuable information regarding steel, which can be obtained in no other way.

Correlation Data.—Most of the work on the correlation of the magnetic properties of steel with its structure and mechanical properties has consisted in the study of a carbon steel of eutectoid composition (0.85 per cent C.). A paper was issued in the early part of the year entitled "The Magnetic Reluctivity Relationship as Related to Certain Structures of a Eutectoid Carbon Steel," and later another was issued on "The Effect of the Rate of Cooling on the Magnetic and Other Properties of an Annealed Eutectoid Carbon Steel." In addition, some work has been done on a series of pure alloys of iron and carbon. Data of this type are fundamental and necessary for the proper development of magnetic analysis.

Detection of Flaws and Imperfections.—The method for the detection of flaws and imperfections has been the subject of some study

during the year. In addition to experiments on the apparatus already constructed, a new instrument was designed and built for the testing of rifle barrels. This was done at the request of the Army Ordnance Department and, upon completion, the apparatus was installed at the Springfield Armory for investigational work there.

Magnetic Test of Twist Drills.—In cooperation with a committee of the American Society for Testing Materials, a test was made of about 40 high-speed steel twist drills which had received various heat treatments. After magnetic tests have been made by different members of the committee, the drills will be given cutting tests to see if any relation can be discovered between the quality of the drills and their magnetic properties.

Magnetic Compasses.

The work on magnetic compasses, aside from the testing of a small number, has consisted of an investigation concerning their use in fighting tanks. This type of service presents some unusual difficulties, but the preliminary results are quite promising. A paper was also issued on the Testing of Magnetic Compasses.

Miscellaneous Activities.

In addition to the experimental work in the laboratory, the magnetic section has cooperated by participation in conferences and work on technical committees with various organizations who are interested in magnetic subjects, including the American Society for Testing Materials, the National Research Council, the National Advisory Committee for Aeronautics, and others.

PHOTOMETRY AND ILLUMINATING ENGINEERING.

General Problems in Photometry.

In the solution of the problems in light measurement which have been raised by the rapid development of practical lighting units of large size and high efficiency, slight progress has been made during the year. The adoption of a standard method for the comparison of the intensity of lights of different color is a matter in which international agreement is highly desirable. A meeting of the International Commission on Illumination was held in Paris in June, 1921, and for this meeting the Bureau prepared a report on the status of heterochromatic photometry, summarizing the recent work done here and elsewhere on this problem. A report on primary standards of light was also submitted to the International Commission, and both of these problems were discussed in a paper presented at the December, 1920, meeting of the Optical Society of America.

The growing use of gas-filled and other incandescent lamps with coiled filaments, which can be reliably measured only in an integrating sphere, has made that instrument practically indispensable in any photometric laboratory. The fundamental theory of the sphere as an integrating photometer is simple, but in practice there are many details of operation which require careful analysis in order to avoid errors. There is no satisfactory discussion of the use of the sphere available in English. To meet this lack a general paper on the theory, construction, and use of the sphere has been prepared and will be printed during the coming year.

Instruments for Measurement of Reflected Light.

In the design of lighting installations and in many other problems it is often necessary to know the reflection factors of walls, ceilings, and other surfaces. Until recently the determination of these factors has been feasible only by taking samples to a laboratory provided with special equipment for the purpose. As a by-product of the Bureau's investigations of the use of the integrating sphere in photometry, an absolute reflectometer was devised some time ago. This instrument is described in Scientific Paper No. 391, issued in July, 1920.

Further study of the problem has led to the construction of several other reflectometers, one of which is described in Scientific Paper No. 405, "A Simple Portable Instrument for the Absolute Measurement of Reflection and Transmission Factors." Like the earlier instrument, this reflectomoter makes use of the principle of the integrating sphere and has been found to give correct results on materials having a wide range of reflecting properties.

New Specifications for Incandescent Electric Lamps.

For about 14 years electric lamps have been purchased by the Federal Government under specifications published in Circular 13 of the Bureau of Standards. Progress in the art of lamp manufacture has been so rapid that this circular has had to be revised eight times in order to keep the specifications abreast of current developments. The original specifications covered only carbon filament lamps. In later editions metalized carbon and tantalum lamps were introduced and then discarded, as tungsten-filament lamps gradually displaced them in use. In connection with these radical changes in types of lamps, very great improvements were made in the efficiency and the life required, but no fundamental change was made in the form of the specifications or in the methods of testing.

For the fiscal year beginning on July 1, 1921, new specifications have been adopted, which include important changes in the test procedure for tungsten lamps. The new specifications will be issued as the ninth edition of Circular 13.

The most notable of the changes is the abandonment of the long-established provision that the life of test lamps shall be considered as ended when the candlepower has fallen to 80 per cent of the initial value. The specification of such an end point is convenient and reasonable in the testing of carbon lamps, because those lamps will often burn for a long period after they have become so blackened that they should not be continued in use. In tungsten lamps, however, means have been found to prevent excessive blackening of the bulbs, so that the lamps normally burn out before their efficiency has fallen enough to justify replacing them. The new tests will therefore be based on the total life to the time of burn out, thus conforming more nearly to actual practice in the use of lamps.

The performance of the lamp throughout its life will also be taken into account through two new provisions. One of these is the evaluation of life-test results on the basis of average efficiency throughout life, instead of the initial efficiency; the other is a requirement that the average light flux during the life of the lamp must not fall below a specified percentage of the initial flux.

Tests under these new specifications are intended to give a more complete indication of the performance of lamps than the former specifications did, and thus to discriminate more exactly between types of lamps. In the first application of the new specifications it has, however, been deemed wise to make the requirements moderate. The numerical values adopted for the various requirements have been based on extensive studies of the performance of lamps in tests made by various manufacturers as well as by the Bureau of Standards. It is believed that they have been so adjusted that the change in specifications will involve no injustice either to lamp manufacturers or to purchasers. It is recognized that for the first year the application of the new requirements should be more or less experimental. Improvement in the ratings required will be based on this experience.

The carbon-lamp schedule has been retained because these lamps still find some use, but the specifications for them are practically unchanged from those given in previous editions of this circular.

Inspection and Life Tests of Incandescent Lamps.

The quantity of lamps ordered this year by departments of the Government was considerably greater than during the preceding one, the total number being 3,000,000. The inspections made by the Bureau covered about the same number. This is an unsual and encouraging feature, since it indicates that samples representing practically all lamps ordered were examined by the Bureau's inspector, whereas during previous years considerable quantities have been shipped without inspection. Such shipments without inspection are usually due to urgent need of the lamps, but in most cases it is practicable to place orders sufficiently in advance, so that immediate delivery is not necessary and the full advantage of inspections and tests by the Bureau can be realized.

Of the total quantity ordered 78 per cent were large tungsten lamps, as distinguished from miniature and carbon filament lamps. Among these tungsten lamps the proportion of gas-filled lamps was the same as last year, comprising approximately 16.5 per cent of the number and 45 per cent of the total cost. The average size of gas-filled lamps ordered was between 100 and 200 watts, while 25 and 40 watt sizes have been most common on orders for vacuum tungsten lamps. Tungsten miniature lamps comprised over 6 per cent of the total. Consequently, approximately 16 per cent of the total ordered were carbon lamps, of which about nine-tenths were large lamps. The miniature carbon lamps were mainly instrument lamps required for special service in the Navy Department. It appears, therefore, that carbon lamps are rapidly being relegated to use in locations and under conditions where it would be impracticable to install and operate tungsten lamps, thus conforming to best practice as recommended in the Standard Specifications for Incandescent Electric Lamps under which the inspections and tests are made.

Life tests were completed on about 1,700 lamps. Of these 86 per cent were large and miniature tungsten and the remainder carbon lamps. There are as yet no standard specifications for miniature lamps, but the test results obtained have furnished valuable data for the preparation of such specifications, which are at present under consideration.

At the request of the General Supply Committee special inspections and tests were made of the product of a prospective bidder on Government lamp contracts. A report to the committee on the results of these tests was given due consideration in recommending awards.

Interlaboratory Comparison of Lamp Measurements.

The Bureau again participated in two interlaboratory comparisons involving measurements of light output and electrical properties of large and miniature lamps, respectively. In the first test—that of large lamps—precision readings were first taken on the standard photometers of the Bureau. The lamps were then sent on circuit to various testing laboratories. Final precision readings were then taken at the Bureau. Results obtained by the laboratories were compared with the mean of the precision readings obtained by the Bureau. The laboratories were left free to take such action as they chose to bring their readings into better agreement with the precision values.

In the miniature lamp tests three brands of automobile lamps were run on the spherical photometers at the various laboratories. At the Bureau the standard 88-inch photometric sphere was employed in the recalibration of standards for this work, and the 36-inch sphere, using these standards, was employed in making the measurements. It appeared from the results of these tests that there was need of further standardization of equipment and methods of measurement of miniature lamps and of obtaining and maintaining satisfactory standards of light output.

RADIO COMMUNICATION.

Radio Research and Information.

The research projects undertaken by the radio laboratory are determined to a considerable extent by the problems which are assigned to the laboratory and for which certain funds are allotted by other Government bureaus. In addition to work on the general program of radio research attention has been given during the past year to special problems for the Signal Corps, Air Service, and Bureau of Markets.

The files of general radio information, radio patents, the radio library, and radio references are becoming increasingly valuable to men engaged in this work, both in the Government and in outside organizations, and the Bureau of Standards is frequently consulted for information on special subjects. Information has been given to universities and others regarding equipment for radio research and subjects on which investigation should be conducted.

A list of radio-research subjects has been prepared and classified for convenient reference. For this purpose and for the classification of other radio material the laboratory has developed an extension of the Dewey decimal classification to radio which has found wide application. About 150 technical reports have been prepared relative to the work of the laboratory, and many of these are available for use in answer to inquiries regarding radio subjects on which no printed publications are as yet available. Programs of radio

research have been prepared and submitted to the Signal Corps, Air Service and Post Office Department.

Standardization of Terminology.

Continued study was given to the definitions of terms used in radio and to the uses of symbols and notations employed in the publication of the results of theoretical and experimental work on electron tubes and other radio subjects. The Bureau of Standards is cooperating closely with the Standardization Committee of the Institute of Radio Engineers in furthering the general adoption of standardization of this sort.

Variations of Radio Signal Intensity.

During the year four tests of the fading or variation of intensity of radio signals have been conducted with the cooperation of the American Radio Relay League. In each series a group of from 7 to 10 transmitting stations were operated on 2 or 3 nights per week, the signals being recorded simultaneously by approximately 100 observers. It is expected that the analysis of these reports which is now being made will give valuable information on the general nature of the phenomenon of fading and the relations of this phenomenon to the meteorological conditions existing during the time of transmission.

Measurement of Received Signal Intensity.

A study of the various methods of measuring signal intensity was continued, and reports were prepared on the audio-frequency comparison method and the radio-frequency comparison method.

Antennas.

A study was made of the methods of measuring the constants of antennas, and formulas were developed for the calculation of the capacity of antennas of certain types. Measurements were made of the capacity and resistance at various frequencies of condenser antennas constructed in several forms and sizes.

International Union on Scientific Radio Telegraphy.

A member of the Bureau of Standards has been appointed technical secretary of the American branch of the International Union of Scientific Radio Telegraphy. In connection with the work in this organization experiments were conducted on a method of measuring the intensity and direction of strays and atmospheric disturbances, especially at short wave lengths.

Electron Tubes.

A considerable amount of material was collected for a circular on electron tubes in radio communication, but on account of the rapidly changing staff of the radio laboratory and the appearance of other books containing material on this subject the completion of this circular has been indefinitely postponed. A considerable amount of the material is, however, available in the form of laboratory reports.

A theoretical study has been made of the relation of the constants of electron tubes to the geometrical dimensions of the tube elements.

The theory of detector tubes has been studied and measurements have been made of the detector coefficient of a number of types of tubes.

A permanent set for the determination of the characteristic curves of electron tubes has been constructed and measurements made on sample tubes.

Theoretical and experimental work has been done on the power output from electron tubes used as power converters.

Measurements have been made of the voltage amplification of radiofrequency amplifiers, and a permanent measuring set is maintained for this type of measurement.

Radiotelephony.

Several laboratory reports and scientific papers have been prepared on the study of modulation phenomena in radiotelephone circuits, with special attention to the electron tubes used in radiotelephone apparatus.

Conferences were held in Washington and at Provincetown, Mass., with officers of the United States Coast Guard regarding the utility of radiotelephony for communication with life-saving boats of this service. Preliminary experiments to determine the requirements for this work have been conducted, a transmitting and receiving set using a coil antenna and mounted on a motor truck having been employed as one of the communicating stations.

Phenolic Insulating Materials for Radio Use.

A technologic paper entitled "Properties of Insulating Material of the Laminated, Phenol-Methylene Type" has been prepared. This paper has been submitted to and approved by several manufacturers, the properties of whose materials are given in this paper. The Bureau of Standards has received hearty cooperation from these companies in furnishing samples for measurement and in discussing methods of manufacture, and it is felt that the results of the tests are of considerable value in the production of satisfactory insulating materials for radio work.

Miscellaneous Insulating Materials.

The Bureau of Standards has cooperated with the American Society for Testing Materials in the preparation of specifications for insulating varnish, adhesive insulating tape, and dielectric endurance tests. Measurements have been made of the phase difference of a number of miscellaneous insulating materials, such as glass, paraffin, beeswax, wood, halowax, ceresin, and impregnated blotting paper. A condensed summary has been prepared showing the properties and uses of various kinds of insulating materials.

Radio Testing.

The methods of measuring wave length (frequency) have been improved by the development of apparatus which makes possible a very accurate comparison between the radio-frequency current from an electron-tube generator and the upper harmonics of a standard tuning fork. The same apparatus is used for an accurate measurement of the constants of inductance coils. The standard condenser, inductors, and wavemeters have been improved to supply the need

for greater precision in radio measurement. Apparatus has been constructed for the measurement of impedance at frequencies varying from audible frequencies to high radio frequencies. The apparatus for comparing ammeters has been improved, and standard ammeters are available to measure radio-frequency currents from 50 milliamperes to 100 amperes. Wavemeters, ammeters, condensers, and other radio instruments have been tested for Government bureaus, educational institutions, commercial laboratories, and others. An effort is being made to interest commercial testing laboratories in equipping themselves to test radio apparatus. A circular on radio-testing methods is in preparation.

Measurements of Telephone Receivers.

Some preliminary measurements of the voltage sensitivity of telephone receivers and of a standard thermophone were made employing a sound-proof room to minimize interference from outside noises. Experiments were conducted in the comparison of the signal intensity produced by a current of two wave forms, a sine wave and an approximate rectangular wave. Measurements were made of the radio-frequency impedance of a large number of pairs of telephone receivers submitted for this investigation by the manufacturers. These measurements show that the telephone receivers may have electrical resonance at frequencies within the range of those used for radio communication.

Properties of Inductance Coils.

A theoretical and experimental investigation has been made of the capacity and resistance of inductance coils of various types, including the following: Short single-layer solenoid, multi-layer coil of square cross section, flat spiral, elliptically shielded coil. A study has been made of the skin effect in single-layer solenoids and straight wires. Charts have been prepared for use in the design of inductance coils. Methods have been developed for the calculation of the inductance of several special forms of inductance coils. Papers describing this work are in course of preparation at the present time.

Airplane Radio.

Assistance was given to the Air Service in the inspection of radio apparatus for controlling airplanes in flight. Experiments on the use of radio as an aid to aerial navigation included the transmission of signals from two large coil aerials placed at an angle of about 45°. The system makes use of the directional transmission characteristics of coil aerials, the airplane receiving station being able to hold its course by flying along the line where the signals from the two transmitting coils are of equal intensity. This system will doubtless find other applications, as, for example, in guiding ships along a certain course during fog. A study has been made of previous work in an effort to reduce the interference caused in a radio-receiving set by the currents in the airplane engine-ignition system. Experiments have been conducted in the laboratory which indicate that by means of very complete shielding of the ignition wires a satisfactory solution of this problem may be secured. Some consideration has been given to a radio method for an airplane ground-speed indicator.

Direction Finding.

In cooperation with the Signal Corps a direction finder was developed for use on a motor tractor. Two crossed coils are used, so that the signals from the transmitting stations can be heard at the same time and the direction accurately determined. Experiments are still in progress in the improvement of this apparatus.

Radio Fog Signaling.

Improvements were made in the antennas and automatic keys used at the radio beacon stations at Fire Island Lightship, Ambrose Channel Lightship, and Sea Girt Lighthouse in New York Harbor. The direction finder on the lighthouse tender *Tulip* was calibrated, and, after preliminary navigation tests on the *Tulip* and endurance tests of the transmitting stations, demonstration tests were conducted at which the practicability of this system of radio fog signaling was shown to a number of representatives of shipping companies, Government officials, radio manufacturers, and others. Preliminary specifications have been prepared for the construction, installation, and operation of the direction finder on shipboard. An exhibit of the radio fog signal system was prepared for the American Marine League Exposition at Philadelphia, Pa.

Radio Receiving Sets.

The Bureau is receiving an increased number of inquiries for information regarding radio receiving and transmitting apparatus available on the commercial market. Through correspondence with radio manufacturers there has been compiled information regarding radio receiving sets and the parts from which sets can be assembled. At the request of the Bureau of Markets an investigation is being made of receiving sets suitable for use in receiving the radio market reports. A conference was held with manufacturers of apparatus of this type, and preliminary arrangements were made for a field laboratory for conducting receiving experiments.

Radio Broadcasting.

Assistance was given to the Bureau of Markets of the Department of Agriculture in the establishment of an experimental radio market service. Market reports were transmitted from the Bureau of Standards station for about four months before this service was taken over by the Post Office Air Mail radio stations. Technical assistance was given to the Bureau of Markets on such matters as the wave length, speed, and time of transmission, form of reports, and other features connected with the satisfactory transmission and reception of these reports. In conjunction with the Bureau of Markets a pamphlet has been prepared entitled "Radio Information Circular No. 1:-Radio Market Service."

Miscellaneous Applications of Radio.

Radio methods and radio instruments are being used for a large number of scientific and technical purposes. Among those to which the Bureau of Standards has contributed during the past year are the development of apparatus for measuring extremely small lengths, the operation of electron tubes in generating sound, and the develop-

ment of a spark system for studying the timing of electric make-and-break circuits.

ELECTRIC BATTERIES.

Tests of Electrical Batteries.

Forty-eight tests have been made for various Government departments and a few commercial concerns on 566 batteries. The branches of the Government submitting batteries for test were the Panama Canal, General Supply Committee, the Motor Transport Division, the Signal Corps of the Army, United States Shipping Board, the Bureau of Engineering, and the Bureau of Ordnance of the Navy Department. The batteries submitted for test included various sizes of dry cells, flashlight batteries, storage batteries, and railway-signal batteries. In addition to these tests the Bureau has collected and tested 1,192 batteries of various kinds to obtain information required in writing specifications, to prepare circulars of information, and to render assistance to various manufacturers and users of batteries. There were included in these 296 batteries manufactured in England, France, Denmark, and Sweden. These batteries have been tested in a manner similar to the customary tests on American-made batteries in order to learn how the product of American factories compares with that of foreign factories. At the close of the fiscal year this test is still in progress.

Electrical Performance of Dry Cells.

An extended series of tests of dry cells in addition to the routine tests has been carried out, on the basis of which a report was made to the Signal Corps on (*a*) the temperature coefficient of voltage, of short-circuit current, and of capacity; (*b*) the period of useful discharge for different types of cells at different rates of discharge, including discharge at constant current and through constant resistance; (*c*) the potential relations of the positive and negative electrodes of paper-lined and bag-type cells; (*d*) a series of curves showing the ampere-hour and watt-hour capacity of dry cells discharging at different rates; (*e*) a series of tables giving a survey of tests made on the principal batteries of American manufacture and summarizing the results obtained on 800 batteries. There has been a lack of engineering information on the electrical performance of dry cells. The Bureau's circular, No. 79, on this subject has been very favorably received, and it is proposed to rewrite this circular, making use of the data obtained in the investigations that have been carried out during the past year.

Storage-Battery Investigations.

Effect of Impurities in Storage-Battery Electrolytes.—This investigation was begun at the request of the Bureau of Engineering, Navy Department, to determine the cause of failure of the negative plates in the battery of a submarine. Samples of the electrolyte and of the negative plates were submitted. The work consisted of a careful chemical and spectroscopic test of the material. The results of this test emphasized the need of more extended investigation of the effect of impurities in storage-battery electrolyte. Preliminary work on such an investigation was begun at the close of the fiscal year. The results of such an investigation would be of use not only to the

Navy Department, but to the manufacturers and users of storage batteries who have become very numerous through the adoption of the storage battery for starting and lighting automobiles.

Automobile Batteries.—A special report to the Motor Transport Division of the Army was prepared describing the experiments made by the Bureau to determine the service which a battery performs in starting various types of automobiles. During the course of these experiments it was found that the instantaneous measurements of the voltage and current in the battery circuit can afford valuable information as to the performance of the starter system and the engine itself. The oscillograph records suggest the possibility of using this method to study the effects relating to torque, temperature, compression, lubrication, distributor action, and flywheel velocity, in addition to the information obtained about the battery and starter system. The material contained in this report has been published in Technologic Paper No. 186.

Study of Wood Separators.—Wood separators are used in nearly all types of modern storage batteries. The durability of such separators in strongly acid solutions and the porosity which permits the flow of an electric current through them are features of great importance. A method for determining the resistance of these separators has been devised and measurements made of a considerable number of different kinds of wood. These experiments should be extended to include the determination of porosity, the resistance of the wood to the charring action of the acid, and the extent to which these separators liberate deleterious impurities in the electrolyte.

Effect of Low Temperatures on the Voltage of Batteries.

This investigation was made to obtain information required by the Carnegie Institution in designing apparatus to be used at the magnetic North Pole for observations of atmospheric electricity. It was found that both dry cells and storage batteries can give an open-circuit voltage of approximately normal value at temperatures as low as −64° C., the temperature coefficient is small, having positive values at some temperatures and negative values at others. Dry cells at such extremely low temperatures can not, however, furnish an appreciable amount of current. Dry cells after being frozen return to normal when brought back to normal temperatures.

Comparison of American and Foreign Makes of Dry Cells.

Information obtained with respect to the performance of foreign makes of dry cells is of value to the military departments and to the American manufacturers of such cells. For this reason about 300 dry cells from several European countries were obtained through the Bureau of Foreign and Domestic Commerce. In order to obtain the maximum of information with respect to these cells, they have been preserved, following the completion of the electrical tests, by opening the cells, washing out the paste, and preserving the parts after drying in such condition that they may be examined at any time by those interested.

Signal Corps Textbook on Radio Telegraphy.

In connection with the revision of the book on "Principles Underlying Radio Communication," which was prepared by the Bureau

for the Signal Corps, the section on electrical batteries has been completely rewritten. The elementary theory of electrical batteries is outlined and brief descriptions of the various kinds of dry batteries and storage batteries are given. Necessary directions for the proper use of various types of batteries for field and laboratory service are also included.

Preparation of Specifications for Electrical Batteries.

At the request of the Motor Transport Division specifications were prepared for starting and lighting batteries for automobiles. In the preparation of these specifications the Bureau had the cooperation of battery manufacturers and the Society of Automotive Engineers. These specifications were discussed at three conferences and were subsequently adopted by the War Department. The general form of these specifications was worked out during the preceding year, but the adoption of a table of standard sizes of batteries proved to be the most difficult part of the undertaking. The specifications as finally adopted on September 28, 1920, included a table of 14 standard sizes chosen from about 150 sizes now being made by various manufacturers. It was estimated that these 14 sizes would accommodate more than 90 per cent of the American-made cars and trucks of recent models. This fact shows the need for such standardization. If the number of batteries being manufactured could be limited to a reasonable number of sizes, the cost of manufacture could be reduced and a large saving to the general public effected.

A representative of the Bureau was appointed a member of the storage battery subcommittee of the Standards Committee of the Society of Automotive Engineers. This society has now revised its standards to conform to the specifications for starting and lighting batteries prepared by this Bureau for the Motor Transport Division. This material is contained in the report of divisions to the standards committee presented at the meeting of January 11, 1921.

A representative of the Bureau is also a member of the subcommittee on storage batteries of the Standards Committee of the American Institute of Electrical Engineers. A series of standard definitions and nomenclature for storage batteries was prepared and was adopted by the standards committee of the institute on May 19, 1921.

Specifications for railway signal batteries prepared during the preceding year by the Battery Committee of the American Railway Association, with the assistance of a member of the Bureau of Standards, were recently adopted.

Specifications for dry cells previously prepared by the Bureau have now been carefully studied in connection with the large amount of testing carried on during the last year. The results of these tests have shown that in general the specifications prepared by the Bureau are satisfactory and in only a few cases will a revision of these specifications be necessary. It is expected to make use of the large amount of data now available for this purpose.

Standard Cells.

Work on standard cells was confined for the most part to testing, which was noticeably heavier than during the previous year.

Late in the fiscal year ended June 30, 1920, selected standard cells were sent to the National Physical Laboratory in England, and to the Electrotechnical Laboratory in Japan for the purpose of determining the order of agreement of the international volt as realized in the three countries. Unfortunately, the cells sent to England have not yet been returned and the cycle of measurements on these cells has not been completed. Measurements made here and in Japan, however, show the basis of reference in the two countries to be in very close agreement.

RADIOACTIVITY AND X-RAY MEASUREMENTS.

Gamma-Ray Measurements of Radioactive Material.

The amount of gamma-ray testing of radium and mesothorium has been so very heavy that practically all other work of the section has had to give way to it. For this reason, and because of the lack of sufficient competent help, there has been no opportunity for investigation and research work. As in the preceding year, requests for X-ray and luminous material tests have not been encouraged, while many requests for alpha-ray and beta-ray examinations of crude materials and partial concentrates have been refused, of necessity, though some of this work, especially that on partial concentrates, seems to the Bureau to be very important.

During the year 2,058 preparations, totaling 35,670 milligrams, or over 35½ grams, of radium and mesothorium were measured and certified by the section, while during the entire preceding six and one-half years a little less than 58 grams were tested and certified. The material certified during the fiscal year 1921 has a market value of $4,000,000.

The increase of the work during the seven and one-half years since routine testing of these materials was begun by this Bureau is shown in the following table:

Year.	Number of tests.	Equivalent milligrams of radium.	Year.	Number of tests.	Equivalent milligrams of radium.
1914 (half year)	28	486	1917–18	1,248	5,376
1914–15	98	2,097	1918–19	1,068	13,367
1915–16	177	4,531	1919–20	1,413	25,278
1916–17	292	6,638	1920–21	2,129	35,565

As the different radium-producing companies now quite generally have their radium preparations certified in their own names and returned to the company's office, the Bureau has no satisfactory or complete data on which to base estimates as to the quantity of material exported. However, information is at hand showing that during the fiscal year radium preparations were exported to Canada, England, Holland, Belgium, France, Italy, Japan, India, Denmark, Australia, Argentina, Brazil, Peru, and Porto Rico.

Self-Luminous Materials.

These materials are composed chiefly of phosphorescent zinc sulphide, with a very small percentage of radioactive material, and are

used wherever a faint and entirely self-contained illumination is desired. A few years ago certain investigations were made by this Bureau concerning the amount of illumination which was necessary under various conditions, and the degree of brightness of different materials, as well as their effective life. Financial limitations and the large amount of gamma-ray testing demanding attention has made it impossible to do much along these lines during the year just closed. Many requests have been received from manufacturers, Government departments, and private individuals for detailed information as to the exact composition and methods of synthesis of the various self-luminous compounds, but as these data are largely held as commercially secret very little information is available for dissemination. Eighteen hundred samples of radium luminous tubes selected from a purchase of 180,000 by the Bureau of Ordnance are now about to be tested for luminosity.

X-Rays.

As mentioned above, the Bureau's X-ray investigations have for the present been practically discontinued. A very few radiographs of samples of metal have been made for the purpose of detecting flaws. Much work yet remains to be done in the investigation of operator-protecting screens and materials for fluoroscope screens, as well as in the standardization of methods of measuring or gaging X-ray intensity, penetration, and therapeutic dosage. Limitations of time and funds have prevented the support and attention that this work deserves.

ELECTROLYSIS PREVENTION.

Electrolysis Problem Among Public Utilities.

The majority of the street railways of the country are operated on the single overhead-trolley plan, with the electric current flowing into the rails through the car wheels after it has passed through the car motors. The current then flows back to the generating station or substation by way of the tracks and earth, some of it, however, often flowing through underground gas and water pipes and the lead sheaths of underground telephone and electric-light cables and sometimes through reinforced-concrete structures. The earth conducts electricity by virtue of its moisture and the salts dissolved in it, which render it an electrolyte. Hence, when the electric current flows away from the iron pipes or lead cable sheaths it carries away iron or lead by electrolytic action, and this in time may seriously corrode the pipes and shorten their useful life, sometimes completely destroying them in a relatively short time. The property damage caused by these earth currents when they are considerable affects to a greater or less degree all the public utilities.

The trouble is the more serious in places where the soil has a greater conductivity than usual and where the conductance of the tracks is small in proportion to the current and the distance the current travels back to the stations is relatively great. Many remedies have been proposed and tried, but no standard practice for the handling of the return current has ever been agreed upon in this country. As the electric railways have been extended and traffic has become heavier, the volume of current handled has increased very greatly,

and the resulting destructive effects, which are cumulative with time, have become increasingly evident. In some cases litigation has resulted between the pipe-owning companies suffering damage and the railway companies whose current causes the trouble. However, in spite of the fact that the courts have considered the question of legal responsibility, these cases have done very little to prevent the trouble in an effective and economical manner.

Economic Importance of the Electrolysis Problem.

The subject of electrolysis of underground pipes, cables, and other metal structures is one which has been given more attention in recent years than formerly, but it still does not receive the attention in many quarters that its importance deserves. When one considers the enormous value of the pipe and cable properties buried in the streets of cities and forming in many cases transmission networks between cities throughout the country, and considers further that there are very few water, gas, or lead-cable systems which are not more or less subject at some points to electrolytic damage from stray currents, it is possible to form a better judgment of the practical importance of this subject. The water and gas pipe systems of this country alone have an aggregate value at the present time in excess of a billion dollars, and, in addition to this, there is a vast extent of underground lead-cable systems belonging to telephone and electric-power companies and to municipalities. There are also possibilities of trouble in the case of bridge structures, portions of steel-frame buildings, and piers, which are occasionally exposed to damage from this source.

While the total losses due to shortening the life of underground pipes and cables must be considerable, such loss does not by any means represent the total annual damage due directly to electrolysis. It is well known that the annual loss caused by leakage of water and gas from distribution systems is very great. It is true that only a part, and probably a small part, of the total leakage is traceable solely to electrolysis; but it is only necessary to assume that a small per cent of the total is brought about by the more rapid development of leaks caused by electrolysis in order to make the total loss resulting from this cause run well into the millions annually.

Inconvenience and Hazard Due to Electrolysis.

It is not alone the property loss, however, that makes the electrolysis problem one of importance. An important fact is the inconvenience to consumers of water, gas, and telephone service resulting from the interruption of the service when repairs are made necessary by electrolytic damage. Possible interruption of the service of police and fire-alarm systems is also one of considerable importance to almost every municipality.

Wherever currents are permitted to flow on the underground pipe systems there is the possibility of electric arcs being formed when pipes are disconnected or when different pipe systems make momentary contact. Accidents of this kind are rare, but they have sometimes occurred, resulting in the loss of life and a considerable damage to property. Cases have occurred also in which leakage of gas resulting from electrolytic corrosion of the pipe has given rise to explosions with disastrous results. Many gas explosions in base-

ments and manholes have occurred, and, although it is difficult to determine what proportion is brought about by electrolysis, undoubtedly some of them are due to this cause.

A water-pipe line weakened by electrolytic corrosion may even present a fire hazard much greater than would result from interruption of water supply at normal times. In many cities it is quite common practice during bad fires to increase temporarily the water pressure in the district adjacent to the fire. It is obvious that a badly corroded water main might be capable of withstanding the normal pressure on the system, and thus give no warning of the weakened condition of the pipe; but at the critical juncture during a bad fire, when the pressure is suddenly increased the pipe may burst, and thus seriously hamper the work of fire fighting. It will readily be appreciated that in any region in which electrolysis damage is in progress to a greater or less extent the mains are far more likely to break at these critical times than at any other period, and thus a real, though indirect, fire and life hazard due to electrolysis must be recognized.

Investigation of Lead Corrosion Troubles in St. Louis.

The investigation of the corrosion of lead cables in the city of St. Louis, mentioned in last year's report, was completed during the past year and the final report submitted. This investigation showed that there were in all five separate causes contributing to the burn outs which in the order of their importance are as follows:

1. Electrolysis due chiefly to lack of drainage at the time the cables were installed.
2. Overheating, due to deterioration of the insulation as a consequence of injury to the sheath, and possibly, also, to the nearness of the ducts to the surface of the streets and the restriction of circulation of the air by the use of too small a duct.
3. Chemical corrosion during the periods in which the street railway substations were inoperative due to the collection of alkali about the sheaths as the current flowed through the earth to them.
4. Surges set up by switching and burn outs.
5. Mechanical injuries, etc.

The investigation of these burn outs brings out the importance of a careful provision against electrolysis at the time of the installation of underground cables and the dangers of chemical corrosion due to too heavy drainage.

Cooperation with the American Committee on Electrolysis.

About a year and a half ago definite arrangements were made for active cooperation with the American Committee on Electrolysis in the further prosecution of electrolysis investigations. This committee consists of 27 members, 3 each representing the following organizations: American Institute of Electrical Engineers, American Electric Railway Association, American Railway Engineering Association, National Electric Light Association, American Gas Association, Natural Gas Association, American Telephone and Telegraph Co., American Water Works Association, National Bureau of Standards.

It will be seen that the Bureau has in this investigation the active cooperation of all the great national associations of utility companies. During the past year somewhat extensive field investigations have been carried out in close cooperation with this committee, the utility interests themselves having incurred considerable expense in connection with these researches. It is planned to continue this cooperation during the coming year.

Development of Apparatus for Making Electrolysis Surveys.

One of the most serious obstacles to satisfactory prosecution of the cooperative work by the Bureau of Standards and the American Committee on Electrolysis has been the fact that existing methods of electrolysis testing are wholly inadequate and do not give definite and reliable information from which correct conclusions can be drawn. The Bureau and the utility interests participating in this work have long recognized the great need of the development of new and improved methods for carrying out tests of this character.

During the past year the Bureau has pushed vigorously the development work on some entirely new methods and apparatus for carrying out tests of this character and with very promising results. The Bureau is now experimenting in the field in a preliminary way with some recently completed testing sets, which, if they continue to prove successful, will place electrolysis testing on a much more scientific basis than it has occupied heretofore. There is urgent need of a thorough study of these new test methods in the field under practical conditions, with the view of determining their sphere of usefulness and of developing the technique of their application. It is planned to make this the first and most important subject of the joint investigation to be carried on during the coming year by the Bureau of Standards and the utility associations cooperating with it.

Electrical Telemetric Devices.

During the past year a large amount of work has been done by the Bureau in the application of a new electrical telemetric device for the measurement of stresses in structural members. This device consists essentially of a series of contact resistances, preferably of carbon, so arranged that the phenomena to be measured, such as pressure or displacements, will cause variations in the contact pressure of the contact resistance, and consequently cause variations in the electrical resistance of the unit. These variations in the electrical resistance can be indicated or recorded at any desired remote station. The chief applications of this device at the present time have been in the measurement of stresses, and the work done by the Bureau has been with particular reference to the measurement of stresses in airplane stay wires and in portions of the rigid frame of lighter-than-air machines.

A number of instruments have been designed and built for the Naval Aviation Service, and these are now almost completed and will be given a preliminary trial in a few weeks. The Bureau plans to continue development work on some recording devices for use in connection with these instruments at the special request of the Bureau of Construction and Repair of the Navy Department.

SAFETY ENGINEERING AND SAFETY STANDARDS.

National Electrical Safety Code.

The Bureau has been engaged for eight years in a study of the life hazard in electrical practice and in the preparation and application of the National Electrical Safety Code. In this work it has had the cooperation and assistance of a large number of engineers, many of whom are connected with the electrical operating and manufacturing companies, others being engineers and inspectors of State commissions, municipalities, and insurance underwriters. The various national associations connected wth the electrical industry have also cooperated effectively in this work. The importance of having a national code, uniform in all the States, is generally realized, and also the advantage of having such a code prepared and presented by a national agency that can study the subject thoroughly and consult all the interests affected. The safety code consists of four principal parts, as follows:

1. Rules for the installation and maintenance of machinery, switchboards, and wiring in central stations and substations.
2. Rules for the construction and maintenance of overhead and underground lines for the transmission and distribution of electrical energy and intelligence.
3. Rules for the installation and maintenance of electrical apparatus and wiring in factories, residences, and wherever electricity is utilized for light, heat, or power.
4. Rules to be observed by operators in working on or near electrical machines or lines.

The code is intended to be adopted by State industrial and public service commissions and municipalities and to be complied with by public service and industrial corporations. It is also intended to be adopted voluntarily by electrical interests when the code has been adopted by any administrative body having jurisdiction in their district.

The Bureau's thorough study of the diverse conditions under which electricity is generated, distributed, and utilized, and of the effect of the rules on operating and construction costs, has secured a code which involves no unreasonable expense, but in general assures an adequate measure of safety and a useful standardization of practice. The large number of conferences held in all parts of the country for discussion of preliminary drafts of the code aided largely in its development. The varying conditions in different geographical sections and in thickly and thinly populated districts have been given careful attention.

The code was published originally in two installments for examination and criticism—the operating rules were published in August, 1914, and revised in May, 1915, the construction rules were published in April, 1915. Both operating and construction rules, again revised after a general conference of all interests in Chicago in the spring of 1916, were combined in a single volume, Circular No. 54, which was published in November, 1916, with a recommendation for actual field trial.

The third edition of the Electrical Safety Code was published under date of October 31, 1920, but was not actually issued until the early part of 1921. This edition is known as Handbook No. 3. The

discussion has been separated from the rules and issued as a separate volume known as Handbook No. 4. Both the rules and the discussion have been extensively revised and amplified, and this edition of the rules is in suitable form for adoption by State commissions, municipalities, and other agencies having appropriate jurisdiction. Such mandatory application of the rules is already being made, the States of Nevada, Tennessee, and North Dakota having adopted rules based on the third edition and a number of others having them in course of preparation. Other administrative bodies had previously adopted rules comprising this code in whole or in part, and it is generally recognized as the most complete and satisfactory standard in its field.

A pictorial edition of the rules showing their application by illustrations is in course of preparation. It is also expected to publish a volume of engineering data referring to matters connected with the rules or with overhead-line construction. These data will include more extensive tables for the sags of conductors and will include tables regarding the supporting structures, such as wood poles and steel towers.

Electrical Safety Conference.

The Electrical Safety Conference has been organized to promote by cooperative action the orderly, consistent, and proper development of practice in electrical manufacturing and installation with regard to accident hazards. Its membership includes representatives of the Associated Manufacturers of Electrical Supplies, the Electric Power Club, the National Workmen's Compensation Service Bureau, Underwriters Laboratories, and the Bureau of Standards. Detailed standards for construction and installation of apparatus will be worked out in harmony with the Electrical Safety Code. The conference has already issued a standard for Industrial Control Equipment and has a number of others in course of formulation.

Industrial Safety Standards.

As a result of the work on the National Electrical Safety Code and the numerous points of contact thus established with State authorities and others interested in safety work the Bureau has been called upon to enlarge the scope of this work and to consider safety requirements in other than the electrical industry. In order to arrange for more complete cooperation in this work and to insure the coordination of the efforts of all parties concerned, a conference was held at the Bureau on January 15, 1919, which was attended by more than 100 representatives of different organizations concerned with safety standards.

On December 8, 1919, another conference on industrial safety codes was held at the Bureau and was attended by representatives of all interests from many parts of the country. The conference voted in favor of having safety codes prepared under the auspices of the American Engineering Standards Committee. It also provided for the formation of a joint safety code committee to prepare a list of codes already in existence or urgently needed and to recommend sponsors for preparing and revising these codes. Such a committee was organized by the National Safety Council, the International Association of Industrial Accident Boards and Commissions, and the

Bureau of Standards. This committee is known as the National Safety Code Committee. It has made recommendations to the American Engineering Standards Committee for about 40 codes, and most of the recommendations have been approved by that body.

The codes recommended for sponsorship by the Bureau of Standards are the following:

Electrical Safety Code.
Gas Safety Code (joint sponsorship with the American Gas Association).
Code for the Protection of Heads and Eyes of Industrial Workers.
Combined Electrical Fire and Safety Code (joint sponsorship with the National Fire Protection Association).
Code for Protection against Lightning (joint sponsorship with the American Institute of Electrical Engineers).
Safety Code for Logging and Sawmill Operations.
Safety Code for Aeronautics (joint sponsorship with the Society of Automotive Engineers).

A number of safety codes are being developed by sectional committees organized by other Federal bureaus and engineering societies as sponsors. The Bureau is represented upon a number of these committees and is doing active work in cooperating with such committees in the development of these codes. Among those in the preparation of which the Bureau has given active assistance are the Elevator Safety Code, the Code for Safe Guarding Power Transmission Apparatus, and the Code for the Woodworking Industry.

Heads and Eyes Code.

The National Safety Code for the Protection of the Heads and Eyes of Industrial Workers was completed and published during the year, and it has been approved by the American Engineering Standards Committee. This code states the type of protection needed in various groups of industries and includes specifications for the goggles, helmets, and other devices which shall be used to provide such protection. It has been generally recognized as the most authoritative work upon this subject.

Logging and Sawmill Code.

A rough draft of this safety code was prepared from a study of existing requirements and the Bureau's general knowledge of such operations. Field inspections were made by members of the staff in the Virginia woods, and later in the South as far as Louisiana, and in New York State and New England. As a result of these field inspections a revised draft of this code was prepared and has been circulated among those interested in the subject as a tentative suggestion to be used as a basis for the complete code. Comments and criticisms upon this draft have been gathered and submitted to the Sectional Committee, which is cooperating in the completion of this code. Additional material has also been prepared and it is expected to issue a complete code during the forthcoming year. The Sectional Committee referred to has been organized according to the scheme of procedure of the American Engineering Standards Committee and contains representatives of all interests concerned with this code.

Aeronautical Safety Code.

A Sectional Committee has been organized to cooperate with the Bureau and the Society of Automotive Engineers in the develop-

ment of an Aeronautical Safety Code, which will include the requirements for airplanes, balloons, landing fields, etc., and will specify the qualifications for aviators and the traffic rules to be observed in the navigation of the air. A preliminary draft of such a code has already been prepared.

GAS ENGINEERING.

Gas-Appliance Investigations.

The principal activity of the gas engineering section during the past year has been the continuation of the investigation on gas burners. A great deal of laboratory work on this subject has been carried on, and the results of the first part of the work are reported in Technologic Paper 193, "Design of Atmospheric Gas Burners," now in press. The application of these fundamental data was made in an investigation conducted during the latter part of last summer in Pittsburgh, the results having been published recently by the Natural Gas Association in a pamphlet entitled, "How Natural Gas Burners Can Be Improved." A great deal of interest has been exhibited by the manufacturers of gas appliances, gas companies, and consumers in the results of these investigations, and it is hoped that this work will stimulate the designing of more efficient appliances and will assist in showing how gas appliances can be adjusted to give the very best conditions for high efficiency.

At the Natural Gas Association Convention in Cincinnati in May the gas engineering section had charge of a very elaborate exhibit, showing the most efficient methods of utilizing natural gas, together with the best type of burners to use. This exhibit created a great deal of interest, and the Bureau has received many requests to continue and expand its work of this character.

In connection with the appliance investigations laboratory studies have been carried out relating to methods of determining small quantities of carbon monoxide in the products of combustion from gas burners. This is an extremely important matter, and the Bureau hopes that with the apparatus and methods now being tried out this problem will be solved.

Gas-Service Inspections.

The Bureau has received during the past year numerous requests from public service commissions and municipalities for investigations of gas service, but the lack of men and funds to carry on outside work has made it impossible to do very much along this line. An investigation was made of the gas-service conditions at Atlanta, Ga., where it was found that the principal difficulty was lack of necessary equipment to make enough gas and distribute it properly. The Railroad Commission of Georgia consequently permitted an increase in the price of gas to allow the company to install the facilities required. This increase was very strongly objected to by the citizens of Atlanta, but it appears that the action of the commission was justified, since a recent valuation of the gas company's properties and an investigation of the operating costs has shown that a higher rate was necessary.

Another investigation of gas-service conditions was made in Columbia, S. C. The Bureau's report in this case settled a number of questions that were in controversy between the city and the gas company.

Investigation of the Cost of Manufacture and Distribution of Gas in the District of Columba.

By an order of Congress an exhaustive investigation of the cost of manufacture and distribution of gas in the District of Columbia was made and a report rendered to Congress. The results of the investigation showed that the cost of supplying the United States and District of Columbia Governments was not materially lower than the cost of supplying the private consumers. A slightly lower rate to the Government is justified by the larger consumption per meter and the somewhat better load factor. The street-lighting contract was found to be a source of considerable loss to the company, which has to be made up by higher gas rates to the general public. This report has received very favorable consideration by the gas companies of the country, especially the Bureau's recognition of the fairness of the service charge, in which everyone is interested at the present time.

Cooperation with the California Railroad Commission.

The California Railroad Commission is directing the work of the Joint Gas Investigation Committee of the State of California, which is investigating the cost of manufacture and the relative usefulness of different qualities of gas. This work has been carried on during the past year and is to be continued during next year. Because of the fact that the opinions of the Bureau with regard to the second question are rather definitely on record the California commission did not extend to the Bureau a formal invitation to join in this investigation, but considerable information which will be of benefit in the work has been given them. A representative of the Bureau spent some days with the engineer in charge of the investigation, going over all the plans for the work and giving him the benefit of the Bureau's experience in similar work.

National Gas Safety Code.

Considering the small amount of time available for this work during the past year, the progress on the Gas Safety Code has been very satisfactory. The Bureau has placed in the hands of the joint sponsor, the American Gas Association, the first five parts of the code. The gas association has been actively cooperating in this undertaking, and it is hoped that before the end of the current year the parts 1 to 5, inclusive, of the code will be ready for publication in tentative form.

ELECTRICAL AND RELATED SERVICE STANDARDS.

Standards for Electric Service.

For some years the Bureau has been studying the questions arising in connection with the formulation of specifications for electric light and power service and the technical and engineering requirements that should be embodied by municipalities or by State public utility

commissions in the ordinances and rules and regulations promulgated by them. Public service commissions in 35 States and in the District of Columbia are empowered by law to ascertain and fix or prescribe adequate and reasonable standards for the measurement of quality and other conditions pertaining to the service rendered by any public utility and to prescribe reasonable regulations for examination and testing of such product or service and for its measurement.

The Bureau's Circular 56, "Standards for Electric Service," covers the field of electric service. This circular contains suggested rules for adoption by State commissions, three model ordinances for the use of cities in States where no commission exists or where cities have regulatory powers in addition to the State commission, and a complete and exhaustive digest of all rules and ordinances in force. Since the publication of the circular many State commissions have used the Bureau's proposed rules as the basis for their regulations. A revision of the circular has been practically completed, bringing it up to date, by including the State laws and rules adopted since the first edition was issued and enlarging and extending the discussion of the engineering features of electric service regulation, particularly in relation to the measurement of demand and power factor. The new laws and revisions of rules have been collected and will be included in the new edition, which will be an exhaustive summary of the technical and engineering features of electric-service regulation. The circular will be republished during the coming fiscal year.

In the work of revision the Bureau has greatly profited, as formerly, in the original preparation by the cordial cooperation and assistance of the public service commissions, municipalities, and public service corporations, the National Electric Light Association, and the Association of Edison Illuminating Companies.

Standards for Heating Service.

Central station heating, either by hot water or by steam, is technically very closely related to electric central station operation, and in 1918 a study of the requirements of central station hot-water heating service was undertaken at the request of the Public Service Commission of Indiana. Field investigations were made in Ohio, Indiana, and Illinois, heating plants visited, and conferences held with operating engineers. The cordial cooperation of the educational committee of the National District Heating Association has been of much value. A proposed set of rules for the regulation of central hot-water heating plants was formulated and submitted to the Indiana commission and, after public hearing and criticism, was made the basis for the rules formally adopted by that commission.

The Bureau has continued its studies of the engineering factors entering into the quality of central-station heating and has the manuscript of a circular on standards for central-station heating partially completed. This contains summaries of regulations so far adopted by States for both steam and hot-water systems and proposed rules and regulations for commission adoption. Methods for calculating "radiation"—that is, customers' heating requirements, engineering phases of contracts with customers, and brief suggested contracts—are included in the study. It is hoped to complete this circular during the next fiscal year with the cooperation of the

special committee of the National District Heating Association and other associations and engineers interested in central-station heating problems.

Standards for Water Service.

Water service is largely furnished by municipalities, there being only a few cities that do not own their waterworks. Many of the smaller urban communities are, however, served by privately owned plants. A number of the public regulating bodies have adopted rules for water service, and there has been some demand for a publication by the Bureau for water service, similar in scope and purpose to the circulars on standards for gas service, for electric service, for telephone service, and for heating service.

The preparation of a circular on water service has, therefore, been undertaken, and a considerable amount of material collected. Field work must, however, be done and engineering studies made before the material can be published. As in all the Bureau's public utility work, the full cooperation of the water utilities, municipalities, city managers, and others interested is obtained before results are made public.

Engineering Standardization Directory.

The Department of Commerce is a member body in the American Engineering Standards Committee, three representatives of the Bureau of Standards being members of the committee. At the request of the standards committee the Bureau has prepared a complete list of engineering and technical organizations engaged in or interested in engineering standardization. Nearly 200 societies and organizations have cooperated in the preparation of this list, and many requests for copies have already been received from Government departments and engineering organizations.

TELEPHONY.

Telephone Service Studies.

The fundamental problem underlying the work of the Bureau on standards for telephone service is to define "service" in such a manner that both its quantity and quality can be made susceptible to measurement. It is of the greatest importance both to the utility and to the public it serves that there be an explicit mutual basis of agreement relating to the amount and quality of service sold by the one and purchased by the other.

An essential prerequisite to work in this field is a detailed technical knowledge of the instrumentalities and methods employed in rendering the service, including their capabilities and limitations, as well as a thorough understanding of the basic scientific and engineering principles underlying the whole.

For several years the telephone section has been applying itself to the study of the whole intricate subject of telephony with the purpose of ultimately determining how the many elements that go to make up telephone service as a whole can be adequately measured. With this end in view, detailed studies have been made of telephone systems in operation in this country. The ever-increasing demand for telephone service and the increase in the cost of labor and mate-

rials require that special consideration be given to labor-saving equipment. The improved manual systems, the semiautomatic, and the automatic switching systems have for these reasons received the most attention. Early in the last fiscal year studies were begun on the "panel type" machine-switching system, so called to distinguish it from the step-by-step automatic system. In this work the Bureau has had the cooperation of the American Telephone & Telegraph Co., which has kindly supplied both drawings and descriptive material. Panel-type equipment is now being installed in some of our large cities. Detailed studies of this system are therefore essential to the successful prosecution of the telephone work as a whole.

The foreshadowed extensive replacement of manual switching equipment by automatic or machine switching equipment, together with the fact that many exchanges will undergo piecemeal conversion, has resulted in special attention being given to the interlinking of the two types of equipment.

Methods of operation, the handling of traffic, the underlying theory of transmission, transmission measurements, and the testing of apparatus and equipment have also been the subjects of particular study. Based on these studies, the preparation of a circular on Telephone Service was undertaken. About the beginning of the last fiscal year mimeographed copies of this circular were submitted to all State utility commissions, to the telephone interests, operating and manufacturing, and to a number of telephone engineers for comment and criticism before final revision for printing. Considerable revision and consequent delay of publication naturally resulted. In addition, further delay was occasioned by the incorporation of a description of the panel-type system. This necessitated first making a thorough study of the electrical, mechanical, and operating principles involved.

No attempt was made in this publication to define standards for telephone service. An effort has been made, however, to give the reader an understanding of what is involved in rendering telephone service. Although much of the material relates more specifically to the subject of telephone practice, it serves as introductory material for a section on the Principal Elements of Telephone Service. The primary object has been to furnish the reader with the elementary knowledge necessary to an intelligent understanding of the material now being prepared for a circular that will treat in considerable detail of telephone service, its grade and grade elements.

The circular on Telephone Service, No. 112, for which there has already been evidenced a very considerable demand, will be ready for distribution early in the new fiscal year. In its preparation the Bureau has had the cordial and helpful cooperation of the telephone interests and of a number of individual engineers and teachers.

Other Telephone Problems.

The manuscript of the proposed circular on telephone transmission, mention of which was made in the last annual report, is undergoing extensive revision and enlargement. It is hoped that it may be published some time during the coming fiscal year.

A paper dealing with the electromechanics of the telephone receiver is in course of preparation. This will treat of the theory of the receiver, with and without eddy current losses, motional im-

pedance circles, electromagnetic properties, motional constants, and efficiency.

Laboratory work in telephony was confined primarily to work on receivers, part of which was in cooperation with the radio section of the Bureau on radio receivers and part was experimental work in connection with the last-mentioned paper.

The Bureau has continued to cooperate with the Standards Committee of the American Institute of Electrical Engineers, through its subcommittee on telephony, telegraphy, and radio, in the standardization of technical terms employed in telephony.

GENERAL CONDITION OF THE DIVISION.

During the year it has been necessary to continue the gradual reduction in the staff of the division which has been going on for the past two years. The total personnel of all classes assigned to the work of this division was 163 at the close of the fiscal year, June 30, 1919, 148 in 1920, and 128 in 1921. Fortunately, this reduction in numbers has been in part compensated for by a notable increase in the stability of the staff. The statistics given last year showed that 61 per cent of the staff had then been in the division less than two years and 31 per cent less than one year. Since that time there have been relatively few new appointments, so that the average length of service of those remaining is practically a year greater than it was then. This improvement brings the double advantage that the newer members of the staff have become more useful, and that the older men have been in part relieved of the necessity of instructing a succession of inexperienced assistants. It is believed, therefore, that on the whole the current output of work has increased rather than decreased during the year.

PUBLICATIONS.

The following papers relating to the work of the division have been published during the year:

Testing of magnetic compasses (R. L. Sanford), B. S. Sci. Paper No. 382.
Measurement of hysteresis values from high magnetizing forces (W. L. Cheney), B. S. Sci. Paper No. 383.
The variation of residual induction and coercive force with magnetizing force (R. L. Sanford and W. L. Cheney), B. S. Sci. Paper No. 384.
The two common failures of the Clark standard cell (E. C. McKelvy and M. P. Shoemaker). B. S. Sci. Paper No. 390.
The measurement of diffuse reflection factors and a new absolute reflectometer (A. H. Taylor), B. S. Sci. Paper No. 391.
Magnetic reluctivity relationship as related to certain structures of an eutectoid carbon steel (C. Nusbaum, W. L. Cheney, and H. Scott), B. S. Sci. Paper No. 404.
A simple portable instrument for the absolute measurement of reflection and transmission factors (A. H. Taylor), B. S. Sci. Paper No. 405.
Effect of the rate of cooling on the magnetic and other properties of an annealed eutectoid carbon steel (C. Nusbaum and W. L. Cheney), B. S. Sci. Paper No. 408.
Automatic apparatus for intermittent testing (G. W. Vinal and L. M. Ritchie), B. S. Tech. Paper No. 171.
Oscillograph measurements of the instantaneous values of current and voltage in the battery circuit of automobiles (G. W. Vinal and C. L. Snyder), B. S. Tech. Paper No. 186.
Standards for gas service, fourth edition, B. S. Circular 32.
The operation and care of vehicle type batteries, B. S. Circular No. 92.

Telephone service, B. S. Circ. No. 112.
National safety code for the protection of the heads and eyes of industrial workers, B. S. Handbook No. 2.
National electrical safety code, B. S. Handbook No. 3.
Discussion of the rules of the national electrical safety code, B. S. Handbook No. 4.
Station performance during Bureau of Standards American Radio Relay League tests of June and July, 1920 (S. Kruse), QST, 4. September, 1920.
The Bureau of Standards—American Radio Relay League tests of short-wave radio signal fading (S. Kruse), QST, 4, November and December, 1920.
Radio signal fading phenomena (J. H. Dellinger and L. E. Whittemore), Jour. Wash. Acad. of Sci., 11, p. 245, June 4, 1921.
The distributed capacity of inductance coils (G. Breit), Phys. Rev., 17 p. 649, June, 1921.
The precision of photometric measurements (F. K. Richtmyer and E. C. Crittenden), Jour. Opt. Soc. of Amer., 4, p. 371, 1920.
Radio communication.—Elementary explanation of the principles of radio telegraphy and telephony (J. H. Dellinger), Sci. Amer. Monthly, p. 157, February, 1921; also, Radio News, 2 p. 678. April, 1921.
The radio work of the Department of Commerce (J. H. Dellinger), QST, 4, June, 1921.
Blindfold navigation.—By radio (F. A. Kolster), Shipping, 13, Feb. 25, 1921.
Radio communication with postal aeroplanes (J. L. Bernard and L. E. Whittemore), Aerial Age Weekly, 13, pp. 105, 127, 155. Apr. 11, 18, 25, 1921.
Review of radio telephony (J. H. Dellinger), Electrical World, Jan. 15, 1921.
Measurements on audio-frequency amplifiers (L. M. Hull), Wireless Age, 8, p. 12, June, 1921.
The cathode-ray oscillograph and its applications in radio work (L. M. Hull), Proc. Inst. of Radio Engineers, 9, p. 130, April, 1921.
Safety to life (M. G. Lloyd), Electrical Inspector, p. 8, December, 1920.
The need for a national logging and sawmill code (J. A. Dickinson), Safety Engineering, December, 1920.
Standardization and safety (C. E. Oakes and J. A. Dickinson), American Machinist, July 1, 1920.
Memorandum on the execution of Italian semirigid airships observed at the front (A. Halsted), Air Service News Letter, 5, No. 8, Feb. 26, 1921; also in Aviation and Aircraft Jour. 10, No. 11, p. 341, Mar. 14, 1921.
How natural gas burners can be improved (I. V. Brumbaugh and G. B. Shawn), Natural Gas, May, 1921.

The following papers are in press:

Power factor of polyphase systems (F. B. Silsbee), presented before the American Institute of Electrical Engineers, to appear in transactions of Am. Inst. of Elec. Eng., 1920.
Standard specifications for large incandescent electric lamps, ninth edition, B. S. Cir. No. 13.
Some major problems in photometry (E. C. Crittenden and J. F. Skogland), to appear in Journal of Optical Society of America.
Atmospheric corrections for the Harcourt standard pentane lamp (E. B. Rosa, E. C. Crittenden, and A. H. Taylor), to appear in Journal of Optical Society of America.
Electrolytic corrosion of lead by continuous and periodic currents (E. R. Shepard), to appear in Transactions of American Electro-Chemical Society, 1921.
Design of atmospheric gas burners (W. M. Berry, I. V. Brumbaugh, G. F. Moulton, and G. B. Shawn), B. S. Tech. Paper No. 193.

3. HEAT AND THERMOMETRY.

Establishment of the standard scales of temperature throughout the range of measurable temperatures; testing and standardization of thermometers, pyrometers, and other temperature-measuring instruments; determination of specific and latent heats, heats of reaction, melting and freezing points, and other properties of materials in the determination of which precise heat and temperature measurements are the principal requirements; standardization of calorimeters; production and distribution of standard heat and temperature samples; industrial applications of heat and temperature measurements; determination of fundamental engineering data involving thermal constants; determination of the fire-resistive properties of structural materials; investigations relating to automotive power plants, fuels, and lubricants.

THERMOMETRY.

This section is concerned with researches on the standard scale of temperature and thermometric fixed points from the lowest attainable temperature up to about 500° C.; maintenance of working standards within the above range; methods of standardizing temperature-measuring instruments, such as liquid in glass thermometers, vapor-pressure thermometers, resistance thermometers, thermocouples; the testing and certification of temperature-measuring instruments; and methods of measuring temperatures.

Clinical Thermometers.

The number of clinical thermometers tested during the year, 26,336, is only slightly larger than the number tested in previous years. The change in the character of the thermometers tested is, however, a notable one, since over 95 per cent of the thermometers tested during the year were for veterinary use.

One State government submitted for test during the year 2,570 veterinary clinical thermometers and 12 thermometers for human use.

It is a remarkable commentary on the appreciation by medical men of accuracy in a clinical thermometer, one of their most important instrument of diagnosis, when it is pointed out that the Bureau was called upon to test over 20 times as many veterinary thermometers as thermometers intended for use in connection with human beings.

It should not be inferred, however, that the question of accuracy in thermometers intended for human use has been entirely neglected. It is at least encouraging to note that the manufacturers of clinical thermometers have taken a greater interest in the accuracy of their product as shown by the considerable number of their standards submitted for test, as well as by their efforts to improve the quality of their product by other means referred to below. By providing a uniform and accurate temperature scale which can be used by the manufacturers in graduating their product, the Bureau is able to assist in insuring that a large part of the product will be satisfactory, although no means of preventing the sale of defective or inaccurate thermometers is provided. One State and one municipality have adopted regulations to control the accuracy of clinical thermometers sold within their respective territories.

In extenuation of this apparent lack of appreciation of accuracy in clinical thermometers it is only fair to add that medical men have become accustomed to rely on the makers' and jobbers' certificates which are generally furnished with every instrument sold. While it is true that some of these certificates issued by the more reliable

makers are quite trustworthy, it is nevertheless a fact that vast numbers of certificates found on the market are unreliable, and where the accuracy of such certificates has been checked in the laboratories of the Bureau it is quite often evident that they do not at all represent the results of any actual tests, but were merely filled out in the issuing office with all zero corrections.

Two important conferences relating to clinical thermometers were held at the Bureau during the year. At one of these conferences, called at the request of several of the largest manufacturers, the questions discussed related to test requirements which a reliable clinical thermometer should satisfy. Very satisfactory conclusions were arrived at in all of the many technical questions involved. The second conference was called at the request of the American Clinical Thermometer Manufacturers' Association for the purpose of discussing with the Bureau the question of asking for national legislation requiring the official testing of all clinical thermometers offered for sale in, or for export from, the United States. The compulsory testing of all clinical thermometers made in Great Britain for either domestic or export purposes is required, and a similar procedure is followed in France and was then under consideration by Germany, which has since adopted it. As a result of this conference the Bureau submitted to the aforesaid association a preliminary draft of a "model" law embodying the combined views of the Bureau and of those representing the association at this conference. Further consideration of this important question is now in the hands of the association.

Of the 26,336 clinical thermometers submitted for test 91.2 per cent, or 24,011, were certified, showing a marked improvement in the quality of the product submitted this year in comparison with that of last year, when the percentage certified was 85.5. Of the thermometers submitted 0.2 per cent were received broken and 0.2 per cent were broken in test, 1.8 per cent were rejected for obvious defects in construction, 1.2 per cent because their index was too difficult to throw back, 1.6 per cent because the index "retreated." The remainder, 3.8 per cent, was rejected because the correction found in the test exceeded the tolerances that have been adopted for the certification of thermometers of this type.

Laboratory Thermometers.

Partial Immersion Thermometers.—In a note on total and partial immersion thermometers published in the March (1921) issue of the Journal of Industrial and Engineering Chemistry the advantages of using partial immersion thermometers in many ordinary laboratory temperature measurements was pointed out, and attention was also called to the fact that in some cases the use of partial immersion thermometers would be disadvantageous.

Specifications for Laboratory Thermometers.—After consultation with members of the American Chemical Society's Committee on Guaranteed Reagents and Standard Apparatus specifications were prepared for three chemical thermometers, which appeared to be sufficient for almost all ordinary temperature measurements commonly required in the chemical laboratory. Two were partial-immersion thermometers, graduated in single degrees from —20 to

+150° C., and from −10 to +360° C., respectively, while the third, intended for more accurate measurements, is graduated from −5 to +105° C. in 0.2° intervals. These specifications were published by the chairman of the committee referred to in the March (1921) number of the Journal of Industrial and Engineering Chemistry and have been recommended by that committee for adoption by the American Chemical Society. The specifications have been used by the Bureau of Standards in the purchase of a considerable number of thermometers and have also been adopted by the General Supply Committee.

New Edition of Circular on Testing of Thermometers.—The previous edition of this circular contained in addition to testing regulations much general information on thermometry and temperature measurements. The new edition contains only information essential to applicants for tests, together with testing regulations and fee schedules. A new feature is the inclusion of tables of tolerances for thermometers of various types and ranges. Thermometers which are free from defects and which are correct within the tolerances may be certified, while thermometers not complying with the requirements will receive a report giving the results of the test and the reason why certification was refused. This circular is in press.

Treatise on Thermometry.—The general information on thermometry which was included in the previous edition of the circular referred to above is to be incorporated, together with much new material embodying the experience of the thermometric laboratory during the past 10 years in a scientific paper now nearing completion. This paper is to be published under the title "Thermometry."

New Certificate Forms.—New certificate forms and stem correction sheets, which are believed to represent a considerable improvement, were prepared during the year, and the printed forms should be available early in the coming year. The number of separate forms required has been reduced.

Thermometer Testing Equipment.—Two new thermometer comparators, one a large electrically heated water bath and the other a small oil bath for testing short total immersion thermometers, were installed during the year. The former, which is large enough to permit the simultaneous comparison of 24 thermometers, has greatly facilitated the work of testing. The apparatus in the laboratory has been rearranged, and several features designed to facilitate the work of testing have been added.

Thermometer Testing.

While the section has not been able to do its testing as promptly as is desirable, there has been a marked improvement in this respect during the past year. Thus, on July 1, 1920, there were on hand awaiting test in the thermometric laboratories 73 tests, including 756 thermometers, while on July 1, 1921, there were on hand 46 tests, including 288 thermometers, representing arrears of about one month's work. This result has been accomplished with a somewhat decreased personnel, depleted by frequent resignations, and notwithstanding that the demands on the section for testing during the year have greatly exceeded that of any preceding year. This result, however, was not accomplished without some serious sacrifices. The heavy demands for testing have made it impossible for the ther-

mometric section to devote any time to researches having an important bearing on the work of the section. Several important investigations relating to thermometry, the establishment of the temperature scale, and the measurement of temperature have had to be discontinued. A moderate increase of personnel would enable this section again to take up these important researches and at the same time would insure greater promptness in the return of apparatus sent to these laboratories for test. The tests completed during the year are summarized under the caption, "Thermometer, Pyrometer, and Heat Tests."

Platinum Resistance Thermometers.

A paper describing in considerable detail the methods used in the construction of precision platinum resistance thermometers of the standard and calorimetric types was published in the Journal of the American Chemical Society and also as Bureau Scientific Paper No. 407. Considerable improvements in the calorimetric thermometer have resulted in simplifying its construction and reducing its fragility.

It had been known for a number of years that the fundamental constants for a calorimetric thermometer differed somewhat from those of a standard thermometer made from the same kind of wire. It was definitely proven that the difference was due to strains in the winding of the calorimetric thermometer, and a method of annealing was devised to relieve such strains. The constants of calorimetric thermometers so treated are found to be substantially the same as those of thermometers of the standard type, thus removing a possible objection to the establishment of a standard scale of temperature by means of the platinum resistance thermometer.

HIGH TEMPERATURES.

This work includes researches on the standard scale of temperature and thermometric fixed points in the interval from 500° C. up to the highest attainable temperatures; maintenance of working standards in the above range; standardization and distribution of standard samples for thermometric fixed points (for example, a series of pure metals of certified melting points), methods of standardization and the testing and certification of pyrometers, such as thermocouples, resistance pyrometers, pyrometer galvanometers, optical pyrometers, including absorption glasses and color screens, radiation pyrometers, etc.; physical properties of materials at high temperatures, such as emissivity, monochromatic and total, specific heats, melting points of refractories, metals, fire brick, etc., ionization and radiation in gases and vapors, etc.; industrial pyrometry and the measurement of the temperatures in industrial processes; and the annealing of glass.

Industrial Pyrometry.

At the symposium on pyrometry held at Chicago in September, 1919, under the auspices of the Pyrometer Committee of the National Research Council and the American Institute of Mining and Metallurgical Engineers, nine papers were presented by members of the pyrometry section of this Bureau. The collected papers and discus-

sions have been published by the institute as a book of 700 pages, containing 60 separate papers by various authors. The great demand for this book among the technical industries has emphasized the importance of pyrometry, the proper application of which is requisite in all industries using processes involving temperature control.

With the extensive pyrometric installations now in operation in our industries, especially for the heat treatment of steel, locomotive and motor vehicle parts, springs, forgings, tools, annealing and working of nonferrous metals, manufacture of ceramic materials, etc., the art of pyrometry has made remarkable strides. From the days when temperature was estimated by visual observation to the present time, in which a central pyrometer station of a modern plant is nearly as intricate as a telephone central station, has been a period of but a decade. The introduction of automatic and semiautomatic distant temperature control, temperature recording devices, signal systems, etc., has enabled the manufacturer to produce a more uniform and better product with comparatively fewer failures and losses.

In spite of this rapid development of pyrometry no manual describing the use of instruments, methods of procedure, installations for various purposes, calibration, and upkeep of apparatus had been written. At the request of many manufacturers the Bureau undertook the preparation of such a manual and has issued as Technologic Paper No. 170, a book of 326 pages with 187 illustrations, treating these subjects from the practical standpoint. The first edition of 2,000 copies was exhausted two months after publication and is now being reprinted. Large manufacturers have purchased copies for their technical employees, and several universities have adopted the work as a standard textbook. The book is based on the 20 years' experience of this Bureau in meeting problems arising in the industrial application of the science of pyrometry.

Standard Samples for Thermometric Fixed Points.

The Bureau issues samples of various metals, the melting or freezing points of which have been determined with high precision. By this means the standard temperature scale of the Bureau may be distributed to the various technical laboratories. The demand for these samples has been much greater than was at first expected, and metal is now procured in half-ton or ton lots. A new allotment of zinc was standardized this year, but both zinc and aluminum samples are practically exhausted at the present time. A considerable stock of copper and lead is still available.

Research in Pyrometry.

The Standard High-Temperature Scale.—Work is being continued on the more precise determination of the fixed points on the high-temperature scale. Redetermination of the melting point of palladium is now in progress. The purity of the best samples of palladium obtainable has not been satisfactory, and the Bureau has now produced palladium of greater purity than heretofore securable.

The optical system of the disappearing filament optical pyrometer used for the temperature measurements has been carefully investigated, and by proper diaphragming the effect of diffraction around the filament is eliminated. This has increased the precision of a setting so that temperatures in the neighborhood of 1,500° C. may

be measured with a precision of 0.2° C. Specially constructed pyrometer lamps having plane parallel faces fused on by the process described below have greatly assisted in this work.

The globe of the lamp is made from a short section of glass tubing to which are fused flat circular plates of glass. During the process the glass is maintained at a carefully controlled temperature, the annealing temperature of the particular type of glass employed. The cover plates are put in place and fused to the tube by means of a minute oxygas flame. This process makes a perfect joint with no distortion of the surfaces. The glass lamp is then annealed and slowly cooled to room temperature. This process may be used for the manufacture of numerous glass articles where cemented surfaces, ordinarily employed, are unsatisfactory. For example, glass cells for acids and other corrosive liquids, hollow glass prisms, colorimeter parts, etc. A description of the method was published in the Journal of the Optical Society of America, 4 p., 496; 1920.

Life Tests of Rare Metal Thermocouples.—The most widely used instrument for the industrial measurement of very high temperatures is the platinum platinum-rhodium thermocouple. It was noticed that some of these couples suffered appreciable changes in electromotive force, due to heating for the short period required for their standardization. At the request of several manufacturers of pyrometers an investigation was undertaken to determine the magnitude and causes of the changes in the indications of these couples due to long continued exposure to high temperatures, under conditions where the couple is protected from contamination by suitable protecting tubes and the avoidance of reducing atmospheres.

The two makes of this type of couple which are on the American market are of American and foreign manufacture, respectively. It was found that the foreign alloy wire contained a considerable amount of iron as an impurity, and the platinum, as well as the alloy from both sources, contained traces of calcium and copper. The changes in the indications of the couples traceable to impurities in the platinum wires were very small for both makes of couples. The impurities in the foreign alloy wire, however, were observed to cause large changes in the indications of the couple. The information resulting from this investigation has been given the manufacturers, and it is believed that better thermocouples will soon be generally available. In cooperation with the Chemistry Division thermocouple wire of higher purity than has been obtainable elsewhere has been produced.

Heat Treatment of Glass.

In cooperation with the Optical and Ceramics Divisions the investigation on annealing temperatures and methods of annealing glass for the removal of strains and certain inhomogeneities which produce warping, variations in the refractive index, and double refraction, is being continued. Data are thereby being obtained on the condition of the glass when it has been annealed according to the different methods in practice or which have been proposed. These data include measurements on the strain left in the glass, on its performance in and suitability for optical instruments, and on such changes in its physical properties as may be produced by the annealing. Similar investigations are also in progress on ordinary glasses

such as those used in glassware, etc., where the strains must be removed in order to prevent spontaneous breakage. Papers on certain phases of these investigations are in preparation, and one paper was published this year.

Proper furnace construction and temperature control are very essential in annealing glass, and the investigations on the degree of temperature uniformity and accuracy of control required while annealing and cooling the glass are being continued. Results indicate that in practice much time is still being wasted in annealing, especially in the case of ordinary glass.

The methods employed in "hardening" or toughening glass are also being studied. This process is the reverse of annealing and renders glass unfit for optical purposes, while by introducing properly distributed strains makes it much more resistant to mechanical shock. Such glass is valuable for protective goggles, windows, etc.

Investigation in Electronics.

The study during the past decade of the emission of electrons from hot wires has led to several most important and unexpected scientific discoveries of immeasurable value to humanity, as, for example, the Coolidge X-ray tube, amplifiers for transcontinental telephony and wireless telegraphy and telephony, rectifiers, etc. These practical devices have been the outcome of pure research directed especially for the purpose of obtaining more information as to the structure of the atom. It is reasonable to predict that by the continuation of such investigation more devices of benefit to human welfare will be developed and methods will arise whereby our economic efficiency may be increased, as would be the case, for example, if a more efficient form of illumination should result. It is further safe to predict that a radical improvement over the present form of electric lamp, itself most inefficient, can be only the result of pure research in the subject of atomic structure. The great electrical companies realizing this fact are devoting vast sums of money to pure research in this field. The Bureau, on account of the limited funds available for such work, can hope to contribute in only a small measure to the knowledge of atomic structure now so rapidly increasing. It is, however, necessary to keep in constant touch with this branch of physical investigations, on account of the extreme importance of its applications. The work on collisions of electrons and atoms reported last year has been continued, and seven papers bearing upon certain aspects of atomic structure and the mechanism whereby light and radiation are produced in electric arcs have been published. Three other papers are to appear at an early date.

HEAT MEASUREMENTS.

Measurements are made in this section over a wide range of temperatures of thermal properties of materials, such as specific heats, latent heats, pressure-volume-temperature relations for liquids and gases; heats of reaction, particularly heats of combustion of solid, liquid, and gaseous fuels; heat transmission and thermal conductivity. Work is also done on the development of calorimetric apparatus and methods and on methods for temperature control, pressure measurements, measurement of heat transmission, etc.

Practically all of the research work of this section during the year has been devoted to the determination of those fundamental physical constants of materials which find application in refrigeration engineering.

Refrigeration Constants.

Work was continued on the determination of the fundamental constants of refrigeration engineering, an investigation which has been in progress for some years and which was undertaken at the request of the American Society of Refrigerating Engineers. This work was continued with a considerably reduced staff necessitated by the decreased appropriations available. The situation was somewhat relieved by the action of the society referred to who manifested their great interest in the continuance of this work by assigning to the Bureau two research associates to work on these problems.

A report covering all the work completed to date was submitted to the December meeting of the American Society of Refrigerating Engineers. This report included the first half of the new Bureau of Standards tables on the thermodynamic properties of ammonia, namely, that portion of the table relating to the saturated liquid and vapor. This report has been published in the journal of the society.

A paper giving the results of determinations of the specific volumes of anhydrous liquid ammonia in the interval —78 to 100° C. was published in the Journal of the American Society of Refrigerating Engineers, and a Bureau Scientific Paper on the same subject is in press.

Specific Volume of Saturated Ammonia Vapor.—All of the experimental data relating to the specific volumes of saturated ammonia vapor in the interval —50 to +50° C. were obtained last year. The results have not yet been prepared for publication owing to the absence this year of a member of the staff. On his return early next year the preparation of these results for publication will be resumed.

Specific Volumes of Superheated Vapors.

The completion of the tables of properties of anhydrous ammonia will require experimental data on the specific volumes and the specific heat of the superheated vapor. The measurements of the pressure-volume-temperature relations for the superheated vapor are to be made by the well-known constant volume gas thermometer method. The construction of the special bulbs, manometers, thermoregulated baths, etc., has been completed and a few preliminary measurements have been made, which appeared to be sufficient to indicate what sources of error will require special attention in order to reduce their effects to the necessary extent.

Some measurements of the specific volume of superheated ammonia vapor by another method, which involves the measurement of the refractive index of the vapor, have been completed.

Specific Heat of Gases.

The flow calorimeter designed for determinations of specific heat of gases has been completed, installed for operation, and preliminary experiments made to test its performance. This process of assembling

has progressed slowly on account of the complicated construction necessitating tests at various stages to insure both the necessary mechanical strength and integrity, and also the integrity and insulation of the numerous electrical circuits.

The accessory apparatus for operating the instrument is quite elaborate. It includes three thermoregulated baths which separately control the temperature of the instrument, the feed gas supply, and the condenser for collecting the used gas when this can be done. There is also a pressure regulator automatically operated for insuring a steady flow of gas, an orifice flow meter for observing the constancy of flow, and a vacuum pump for evacuating the gas lines, detecting leaks, and also for evacuating the calorimeter envelope in order to minimize the loss of heat by conduction. Mercury manometers for low and a piston gauge for high pressures indicate the pressure of the gas subject to specific heat determination. Temperature measurements are made electrically both by resistance thermometers and by thermocouples.

The preliminary performance tests mentioned above have been quite satisfactory and indicate that the control of the heat losses in the instrument is such as to permit a net accuracy in specific heat determinations comparable with the precision of the various observed elements which enter into the final result. This net accuracy is ample for the purpose of furnishing data for engineering tables, which is the primary object of the investigation. The first data to be sought with the instrument is the specific heat of ammonia gas. This is required to complete the tables of properties of ammonia for the use of refrigerating engineers. Only a few minor construction details remain to be completed before the experimental work with ammonia can proceed.

Mollier Chart.

The Mollier chart is a graphic representation of the data contained in a table of the thermodynamic properties of a material, such as steam or ammonia, and in engineering work is much more convenient to use than the table. It was found that by suitable choice of the coordinates a considerable improvement over the customary heat-content-entropy chart could be obtained. A paper illustrated with several figures to show the form the chart assumes with various coordinates, thus permitting selection of the most suitable chart, is to be published in the Journal of the American Society of Refrigerating Engineers.

Pressure-Relief Diaphragms.

Safety devices to relieve the pressure in a closed vessel, such as a boiler, gas cylinder, etc., are used in large numbers. In connection with certain investigations dealing with gases under pressure it was necessary to install a number of very small pressure-relief devices of this kind. The diaphragm type, consisting of a metal diaphragm closing an opening in a brass plate, was chosen. It was necessary to make a number of measurements of the effect of size of opening, thickness, condition, and material of diaphragm, etc., on the bursting pressure before designing the safety devices which were installed. The data thus accumulated on safety relief diaphragms were collected and have been published in the March (1921) number of the Journal of the American Society of Refrigerating Engineers.

CRYOGENIC LABORATORY (LOW TEMPERATURES).

This work is concerned with the production of low temperatures down to those of liquid hydrogen (ultimately liquid helium) preparation and storage of pure gases, development of methods of producing and maintaining low temperatures, liquefaction and separation of gases at low temperature, and special tests requiring the facilities of the low-temperature plant.

Production of Low Temperatures.

Liquid Air.—The demands for liquid air have increased, and rather large quantities have been supplied both to other laboratories of the Bureau of Standards and to institutions outside the Bureau.

Carbon Dioxide.—The carbon dioxide compressor has been operated very frequently, supplying carbon dioxide to the thermometry section for thermometer comparators, for work on the thermal properties of gases, and for the testing of aviation instruments at low temperatures.

Liquid Hydrogen.—The apparatus for the production of liquid hydrogen has been completed, but time available has not permitted further work with it.

Vacuum-Walled Containers.—Investigations have been made of the influence of various factors upon the rate of heat transfer in vacuum-walled containers with the expectation of being able to construct containers of much greater insulating efficiency than those now in use. This investigation has been frequently interrupted by other work and has not been completed.

Aviation Oxygen Apparatus.—At the request of the Air Service equipment for carrying liquid oxygen in airplanes to supply oxygen for respiration at high altitudes has been designed and constructed. This apparatus is considered to be an improvement over other equipment for this purpose in possessing large capacity for a given weight and in its reliability and safety. Reports have not yet been received of its use in flight.

Production of Liquid Air on a Laboratory Scale.

A paper under the above title, giving details of construction of the Hampson type of liquefiers designed and constructed for use in the low-temperature laboratory, was prepared and submitted for publication as a Bureau Scientific Paper and is now in press. This paper also contains a general description of the liquid-air plant and its accessories and was prepared for the information of those contemplating similar installations, since with the exception of the air compressors the apparatus required for liquefying air can not be purchased in this country.

FIRE-RESISTIVE PROPERTIES OF STRUCTURAL MATERIALS.

The object of the investigations on the fire-resistive properties of structural materials is to furnish architects, engineers, builders, State and city building bureaus, insurance interests, and others with fundamental engineering data relative to the behavior and safety under fire conditions of the various types of building materials and con-

structions. To this end fire tests of structural materials and structural members are conducted; investigations are made to develop engineering data relative to the general fire-resistive features of building construction; tests are made of fire prevention and fire-retarding devices; testing conditions and testing methods are investigated with a view to standardization; and recommendations are made for proper provisions in building codes and fire codes.

Fire Tests of Concrete Columns.

A brief summary of the nature of these tests, which were conducted at the Pittsburgh laboratories of the Bureau, together with some of the more general conclusions, have been given in previous reports.

Detailed descriptions of the results of this investigation have been published in the Proceedings of the American Concrete Institute for 1918, 1919, and 1920. A complete report of the investigation is to be published as a Bureau Technologic Paper, the manuscript for which is now nearly completed.

Fire Tests of Building Columns.

The Bureau's cooperation in this research, which comprised fire tests of 106 columns, conducted jointly with Associated Factory Mutual Fire Insurance Companies and Underwriters Laboratories (Inc.), was concluded during the year. General notes on the purpose, scope, methods of testing, and summary of important test results have been given in previous reports. The full results of the investigation were published during the year as a joint organization report, and also as Paper No. 184 in the Bureau's technologic series.

The report, which contains some 375 pages and numerous illustrations, tables, and curves, contains fundamental engineering data which it is confidently believed will have an important bearing on fire-resistive building construction. The amount of new data made available by this report exceeds many times the total amount of data available in this field before the completion of this research. It is highly desirable that similar data be obtained on other elements entering into building construction.

Fire Tests of Brick Walls.

Tests of brick-wall panels, 11 feet high and 16 feet wide, are being made in the Bureau's testing furnace at Washington. This is the initial series of a number that it is proposed to carry out with this equipment, the intention being to include all the wall and partition materials in common use. It was deemed advisable to introduce the tests with brick first, because brick is a primary building material that has been in long and universal use, and the values obtained with each thickness can be used as a standard of comparison in interpreting the results with other materials. There is at present much demand for information on the fire values and stability under fire conditions of brick walls. Opinion as reflected in building ordinances varies greatly relative to wall thickness requirements, and while this is due in part to considerations other than those relating to fire, it is thought that a properly planned series of fire tests will help materially to determine the minimum thickness safe for use.

The panels are built by a masonry contractor at a fixed price per panel, as determined by competitive bids. The series will include tests with brick made of two types of surface clay and one shale, and also with sand-lime and Portland cement brick. Studies will be made on the effect of changing the cement and lime content of the mortar. The panels are either built solidly into their containing frames to approximate conditions of restraint sometimes present in practice, or they are built free from the sides and top of the frame, some with stiffening pilasters at the ends to simulate conditions of use in the upper stories of some buildings. Heat is applied to one side of the panel, using fuel oil atomized by jets of steam or compressed air, and temperatures are measured at a number of points in the furnace as well as on the exposed and unexposed faces of the panel and at intermediate points within it. The relative deflections of panel and restraining frame are measured, as also the deflections of the restraining frame itself. The fire test is continued for six hours, provided failure does not occur earlier. Water will be applied in some of the tests after a one-hour fire exposure.

The series will consist of about 25 tests of 8-inch and 12-inch brick walls of the solid and of the hollow type, of which 9 tests have been completed. During 1920 the equipment was tested out, and some changes deemed necessary were made. Two preliminary tests were made of wood stud and plaster on metal-lath partitions. The work with the brick panels was done during the last five months of the fiscal year. While too early as yet to give definite conclusions, the tests indicate that within limits as to height the 12-inch wall is a stable and effective fire barrier. Relative to the 8-inch wall, less definite statements can be made, although under limitations as to exposure, height of wall, and lateral support, which it is proposed to establish in this and related investigations, the safe use of the 8-inch wall may possibly become adequately defined.

Hollow-Tile Investigation.

Through a cooperative arrangement with the Hollow Building Tile Association an investigation was begun on the fire-resistive and related properties of hollow-clay tile. Clay and hollow tile, representative of the types generally used, are made into specimens for tension, transverse, compression, absorption, freezing, vitrification, fusion, and fire tests. For the latter a gas-fired furnace was built in the ceramic laboratory of the Bureau to accommodate panels up to 3 feet wide and 5 feet high and subject them to working load during the fire test. The panel at present used is 1 foot wide and consists of 8-inch double-cell tile, with which 26 fire tests have been made, the results of which are chiefly of value for comparing the fire-resistive properties of tile made from different clays and in different forms. It is proposed to study the effect on fire-resistive properties of ground-burnt clay (grog) additions to the raw clay in molding; also of burning to different degrees of hardness.

The auxiliary tests indicate large variability in strength and elastic properties, and as yet no definite relation has been established between absorption and compressive strength.

Strength of Materials at High Temperatures.

Brief description of an apparatus for determining the compressive strength and elastic properties of materials as influenced by heat and notes on results obtained in a preliminary series on structural steel, concrete, and timber have been given in previous reports. During the first months of the past year the work on timber, as far as it concerns the present series, was completed, the species tested being longleaf pine and Douglas fir. The equipment was dismantled in consequence of the transfer of the Bureau's Chicago activities to Washington and is now being reassembled with improvements in details that will increase the accuracy of the observations.

Miscellaneous Fire-Resistance Activities.

A room is being equipped for the study of some of the problems connected with fire-resistance work, including, in addition to the investigation noted above, ignition points, spontaneous ignition, porosity, and other auxiliary tests of materials. Some preliminary work was done on ignition points and susceptibility to ignition. At the request of the Steamboat-Inspection Service tests were made of a number of motion-picture projectors relative to the fire hazard involved in their use aboard ships.

Among other miscellaneous activities a few examinations to determine causes of fire and fire damage have been made. Information on the fire resistance or fire hazard of materials and devices has been given in response to requests where it could be done without undue experimentation or research.

AUTOMOTIVE POWER PLANTS, FUELS, AND LUBRICANTS.

The work of this section includes the investigation of the fundamental, scientific, and technical problems related to the design and operation of internal-combustion engines and accessories, and the qualities and characteristics of fuels, lubricants, etc., for use in such engines.

The depletion of the petroleum supply of the country and the consequent demand for better fuel economy in automotive transportation have led to an increased interest in the results of research in the field of more efficient fuel utilization. The Bureau has attempted to use its facilities in such a way as to be of maximum assistance to the industry, as well as to prosecute the researches in progress for the military departments of the Government.

Altitude Laboratory.

The altitude chamber of the dynamometer laboratory has been used for two major purposes: (*a*) Altitude tests of airplane engines in cooperation with the Engineering Division of the United States Army, and (*b*) an investigation of the effect of compression ratio on the performance of aviation engines. Two engines have been tested in cooperation with the Engineering Division—a Maybach 300-horsepower and a B. M. W. Both were considered excellent examples of German design, and a complete test of their altitude performance was desired.

Accurate knowledge as to the influence of compression ratio on engine power and economy is of so great importance that every effort

has been made to make the investigation of this subject as complete as possible. This has necessitated tests covering a wide range of engine speed, engine power, carburetor air temperature, jacket water temperature, etc. The data thus accumulated not only give the desired information concerning the influence of compression ratio, but also much supplementary information as to the effect on engine performance of changes in carburetor air temperature, jacket temperature, etc.

During some of the above tests difficulty was experienced in the engine operation, which was eventually traced to the formation of snow in the manifold. This snow formation seemed a likely source of engine failure in service and one that under service conditions would be hard to detect. A technical note was therefore prepared describing the trouble, explaining its cause, and suggesting its cure.

Eleven reports covering investigations and tests carried out in the altitude laboratory have been prepared, as noted under the heading "Publications."

Ignition.

Ignition problems have been handled jointly by this and the Electrical Division of the Bureau, and a portion of the work is described in the report of that division.

Tests have been made on a number of spark plugs and attachments to be used with them at the request of the Motor Transport Corps and also for other Government departments and for manufacturers.

Tests have also been made upon several special porcelains which have been developed by various manufacturers for use as insulators in spark plugs.

A study has been begun of the effect of the electrical character of the spark upon its ability to ignite gasoline-air mixtures under extreme conditions of mixture ratio and dilutions which may occur in automotive practice. Under such conditions there is some evidence that the character of the spark affects its igniting power, and sparks can be produced which are visible to the eye but which do not produce ignition. Oscillograms have been taken of the current in the spark under such conditions.

A report on The Mathematical Theory of Induced Voltage in High-Tension Magnetos has been prepared for publication by the Bureau, and a second paper on Simplified Magneto Mathematics will appear as a report of the National Advisory Committee for Aeronautics. A short paper on Causes of Cracking of Ignition Cables has also been printed as a technical note of the National Advisory Committee for Aeronautics.

Lubrication.

The general program of the lubrication laboratory is an investigation of the relations between the behavior of lubricating oils in service and the accepted physical and chemical laboratory tests. For this purpose an extended study has been made of a series of oils before and after long-continued service in a typical automobile engine. Oils derived from paraffin and naphthene base crudes were compared to determine, if possible, their relative merits for use as lubricants in automotive engines. While the results of these extended tests

show characteristic differences between the two classes of oils, no significant differences in lubricating value have been demonstrated.

Progress has been made on the development of tests for the behavior of standard stock bearings under various conditions of service and of lubrication, also in the development of a test for the relative values of various oils in preventing seizure of bearings under high unit pressures.

The laboratory has cooperated with the Army in the development of a special oil for recoil mechanism of aircraft machine guns and has undertaken the development of a special test for consistency of aircraft engine oils at low temperatures. It has cooperated with the Interdepartmental Committee on Standardization of Petroleum Specifications in the preparation of specifications for Government purchases. It has undertaken tests of special products for the United States and some of the State governments and in a few cases for private companies.

An extensive series of efficiency tests of rear axles for trucks has included a comparison of power losses with oils and greases with and without the addition of graphite. The results of these tests are as yet inconclusive as to the effect of graphite when used in this manner.

Carburetion.

Two major problems have been under investigation, one of these dealing with mixture control for aircraft engines at altitudes, the other with the distribution of liquid and vaporized fuel in the intake manifold.

As the air grows less dense with increasing altitude, the usual carburetor of an aircraft engine supplies a richer and richer mixture of fuel with air. For economical operation this tendency must be corrected by some form of manual or automatic control. A carburetor which will inherently maintain a correct fuel ratio at all altitudes is almost an essential, particularly for military purposes. A general study of the laws of flow in carburetion is in progress.

The second problem relates to the development of means for measuring and specifying the quality of an air-fuel mixture in the intake manifold. The proper operation of all engines supplied with liquid fuel by a carburetor depends upon the condition of the mixture as it enters the cylinders. Means have been developed for measuring the evaporation which takes place at any section of the manifold.

The characteristics of air flow and mixture ratio were determined for each of two German aviation carburetors, the B. M. W. and the Maybach, and detailed analyses of the operation of these carburetors under various conditions of service were prepared.

As a portion of a study of the subject of the fuel economy of various current automobile carburetors, tests were conducted on six widely used types and the mixture ratio determined for changing loads at different constant throttle openings and for changing throttle positions at different constant speeds.

Phenomena of Combustion.

In order to understand more completely the combustion of fuels in engine cylinders, experimental studies have been made of the rates at which fuel-air mixtures burn under carefully controlled conditions.

The effect of changes in the proportions of air and fuel have been determined with acetylene, and further work with carbon monoxide and gasoline vapor under increased pressures and at high temperatures is contemplated. A new method of studying the combustion of gases at constant pressure has been developed which gives promise of great value.

Some preliminary experiments have been carried out in an engine to determine the rate of passage of the flame through the gas mixture, using as an indicator the effect of the flame upon the breakdown voltage of a spark gap. These showed, however, that the turbulent motions of the gas were so great and so variable from one explosion to the next as to mask any effects from the finite velocity of propagation.

A one-cylinder engine has been used in a study of combustion phenomena. Particular attention has been given to an investigation of the causes of fuel knock and to measurements of pressure that exist when fuel knock is present. In addition to this work short tests of spark plugs, ignition devices, and some fuel comparisons have been made. Included in the latter was a series of runs with hydrogen as a fuel, made at the request of the Balloon and Airship Section of the United States Army.

Cooling Problems.

The staff engaged on this work has completed a systematic compilation and revision of all the research work on aircraft radiators covering the past several years and the preparation of a comprehensive report on the results of this work which will constitute a treatise on the subject of aircraft and other cooling radiators. A considerable amount of new experimental work has been required for the verification of earlier results. In addition an extensive development work of a confidential nature has been carried on for the Army.

Truck Rear Axles.

At the instance of the Motor Transport Division, Quartermaster Corps of the Army, the Bureau has carried out comparative tests on a number of rear axles suitable for Army trucks. This investigation has been only partly completed and includes determination of the efficiency of power transmission of each axle over the whole range of speeds and power transmitted for which the axle is suited and also endurance runs arranged to bring out any weaknesses that may exist.

The purpose of this work is to aid the Motor Transport Division in determining the axles best suited to their requirements in connection with replacements and to obtain information which will be of value in connection with new construction work. Another of the objects of this investigation is to furnish manufacturers information which will be of direct benefit to them in their efforts to improve their product. The endurance tests, by bringing out what parts may be relatively weak compared with the remainder of the structure, are proving particularly useful in this direction. The Bureau expects upon completion of this investigation to be able to publish a considerable amount of data of general interest.

Standard Method of Testing Brake Linings.

Manufacturers and large users of brake lining materials for automotive equipment have long realized the advantages which would result from establishing a standard method for testing these materials.

In the absence of such a method various simple tests were made by some of the makers of linings to keep a check on their product and to try out new types, while car builders specified certain methods of testing the materials for use on their cars. As the conditions of these tests varied widely, the results were usually not comparable.

At the instance of the Motor Transport Corps, the Bureau of Standards has carried on an extended investigation to ascertain the best conditions for a standard test for brake linings. A program was prepared in cooperation with the Motor Transport Corps and the Society of Automotive Engineers' Standards Committee somewhat over a year ago. This provided for investigation of the coefficient of friction of linings; the influence of water, oil, wear, and temperature on this coefficient; tests for durability by means of both long-time runs and severe service runs; also for supplementary tests dealing with tendency of hot linings to stick on drum while cooling, and other features.

The Bureau's work was fully reported on and discussed at a conference held in May and at which representatives of the Motor Transport Corps, the Society of Automotive Engineers, and a large number of makers of linings and others were present. Tentative recommendations for test equipment and methods of test were made by the Bureau.

Further work was necessary before final conditions could be determined on, and this work is being carried out. Meanwhile a number of the makers are installing test apparatus in line with the equipment used by the Bureau and will carry out tests on the basis of the Bureau's tentative recommendations. The results and additional experience thus obtained promise to aid in reaching more definite conclusions.

Miscellaneous.

At the request of the Ordnance Department a test was made on a roof engine to determine the performance of the engine as indicated by the power developed and the weight of fuel consumed per horsepower-hour under full-load conditions when equipped with various induction systems and with heavy and light pistons and connecting rods.

Tests were made on a number of special radiator cores for the Engineering Division of the Air Service, McCook Field, as well as for the Bureau of Steam Engineering of the Navy Department.

A clearance volume indicator and balanced diaphragm engine speed indicator were furnished by this laboratory to the Engineering Division of the Air Service, McCook Field, for use in connection with various engineering problems at that field.

Engine tests were carried out on a number of specially designed spark plugs.

At the request of the Motor Transport Corps a number of special fuel "dopes" and so-called gasoline intensifiers were analyzed and subjected to engine tests.

TESTING, INFORMATION, AND PUBLICATIONS.

Thermometer, Pyrometer, and Heat Tests.

The tests completed in the division during the year are summarized as follows:

The number of liquid-in-glass thermometers of all kinds, exclusive of clinical thermometers, submitted for test was 4,211, of which 2,144 were certified and 1,745 received reports, the failure to receive certificates being due either to defects in design or construction or to the fact that the errors exceeded the established tolerances. Of the remaining thermometers, 131 were broken either when received or in test and 191 were rejected. Among those submitted were 489 calorimetric thermometers, 138 precision calorimetric thermometers, 166 Beckmann thermometers, and 94 clinical standards. Of the remaining thermometers, 1,877 were classed as high-temperature thermometers, being listed at temperatures above 100° C. The increase in the number of high-temperature thermometers submitted represents the most notable change in the character of the testing work. While the greater part of the high-temperature thermometers submitted were found to be suitably annealed, an undue proportion, including several large lots, were rejected due to insufficient annealing. It was found, however, that failure to anneal thermometers was due to carelessness rather than ignorance on the part of the manufacturers. Details relating to testing of clinical thermometers have already been given.

In addition to the above there were tested 29 resistance thermometers and 30 thermocouples, some of the latter being representative of large amounts of wire to be used in fire tests. Fifteen freezing-point tests and a number of special tests of an investigative character were also made.

In the high-temperature laboratories tests were made of 134 thermocouples, 17 indicating instruments for thermocouples, 12 optical pyrometers, 8 lamps for optical pyrometers. Melting-point tests of 35 materials, such as metals, alloys, fire brick, sand, ash, etc., were made. The number of standard melting-point samples distributed was 287.

In the heat-measurements section two gas calorimeters and one mechanically cooled refrigerator were tested, the latter at the request of the Public Health Service. The number of standard combustion samples distributed was 310.

A number of tests completed in the sections dealing with the fire-resistive properties of structural materials and with automotive power plants fuels and lubricants were not of a routine character and have been summarized in the reports on those sections.

Information, Cooperation with Societies, Etc.

An important part of the division activities has consisted in furnishing information on scientific and technical subjects related to its work, by extensive correspondence, reports, or directly to technical men visiting its several laboratories. Information relating to apparatus developed by the division, such as thermometer comparators used in the thermometric laboratories, a precision pressure gauge, resistance thermometers, a clearance volume meter, an engine indi-

cator, etc., has been supplied by means of blue prints and descriptive matter in answer to numerous inquiries. Information which will make it possible to improve the fuel economy of automobile engines has been supplied to manufacturers.

Members of the division have cooperated in the activities of various scientific and technical societies and organizations, including: The American Chemical Society, the American Concrete Institute, the American Society for Testing Materials, the American Society for Steel Treating, the American Society of Heating and Ventilating Engineers, the American Society of Mechanical Engineers, the American Society of Refrigerating Engineers, the American Physical Society, the Association of American Clinical Thermometer Manufacturers, the Hollow Building Tile Association, the New Jersey Clay Products Association, the Optical Society of America, the Society of Automotive Engineers, the Western Society of Engineers, the General Supply Committee, the Associated Factory Mutual Fire Insurance Companies, and Underwriters' Laboratories (Inc.).

The division has been actively represented in the committee work of several of these societies, notably the American Society of Refrigerating Engineers, the American Society for Testing Materials, and the Society of Automotive Engineers. Numerous papers dealing with the work of the division have been presented before scientific and technical societies.

Publications.

The following publications relating to the work of the division have appeared during the year among the publications of the Bureau of Standards and may be obtained from the office of the Superintendent of Documents, Government Printing Office, Washington, D. C. Prices are given in Bureau of Standards Circular 24:

Recent modifications in the construction of platinum resistance thermometers (T. S. Sligh, jr.), B. S. Sci. Papers, 17, p. 49; 1921 (No. 407).

A new microphotometer for photographic densities (W. F. Meggers and Paul D. Foote), B. S. Sci. Papers, 16, p. 299; 1920 (No. 385).

Atomic theory and low-voltage arcs in Caesium vapor (Paul D. Foote and W. F. Meggers), B. S. Sci. Papers, 16, p. 309; 1920 (No. 386).

Ionization and resonance potentials of some nonmetallic elements (F. L. Mohler and Paul D. Foote), B. S. Sci. Papers, 16, p. 669; 1920 (No. 400).

Resonance potentials and low-voltage arcs for metals of the second group of the periodic table (F. L. Mohler, Paul D. Foote, and W. F. Meggers), B. S. Sci. Papers, 16, p. 725; 1920; 1920 (No. 403).

Pyrometric practice (Paul D. Foote, C. O. Fairchild, and T. R. Harrison), B. S. Tech. Paper No. 170; 1921.

Fire tests of building columns (S. H. Ingberg, H. K. Griffin, W. C. Robinson, and R. E. Wilson), B. S. Tech. Paper No. 184; 1921.

The papers listed below have appeared in current scientific and technical publications:

Notes regarding the construction of platinum resistance thermometers and immersion heating coils of low lag (T. S. Sligh, jr.), Jour. Am. Chem. Soc., 43, p. 470; 1921.

Note on partial and total immersion thermometers (C. W. Waidner and E. F. Mueller), Jour. Indus. and Eng. Chem., 13, p. 237; 1921.

Ionization and resonance potentials for electrons in vapors of lead and calcium (Paul D. Foote, F. L. Mohler, and H. F. Stimson), Phil. Mag., 40, p. 73; 1920.

The ionization potential of hydrochloric acid and the electron affinity of chlorine (Paul D. Foote and F. L. Mohler), Jour. Am. Chem. Soc., 42, p. 1832; 1920.

The thermochemistry of ionization of vapors of certain components (Paul D. Foote and F. L. Mohler), Jour. Wash. Acad. Sci., 10, p. 435; 1920.

Resonance potentials and low-voltage arcs for metals of the second group of the periodic table (F. L. Mohler, Paul D. Foote, and W. F. Meggers), Jour. Opt. Soc. of Am., 4, p. 364; 1920.
The absorption of heat in glass (A. Q. Tool and C. G. Eichlin), Jour. Opt. Soc. of Am., 4, p. 340; 1920.
Note on a new method of joining glass (C. O. Fairchild), Jour. Opt. Soc. of Am., 4, p. 496; 1920.
Thermal conductivity of heat insulators (M. S. Van Dusen), Jour. Am. Soc. Heat. and Vent. Engs., 26, p. 625; 1920; also in Jour. Am. Soc. of Ref. Engs., 7, p. 202; 1920.
Specific volume of anhydrous liquid ammonia (C. S. Cragoe and D. R. Harper, 3d), Jour. Am. Soc. of Ref. Engs., 7, p. 113; 1920.
Bureau of Standards report of progress in the determination of the fundamental constants of refrigeration engineering, published in Jour. Am. Soc. of Ref. Engs., 7, p. 338; 1921.
Pressure-relief diaphragms (H. F. Stimson), Jour. Am. Soc. of Ref. Engs., 7, p. 380; 1921.
Gravitation and relativity (C. W. Kanolt), Jour. Franklin Inst., 190, p. 211; 1920.
The relation between the compression ratio and the thermal efficiency of an airplane engine (S. W. Sparrow), Jour. of the Soc. of Automotive Engs.
Intake manifold temperatures and fuel economy (W. S. James, H. C. Dickinson, and S. W. Sparrow), Jour. of the Soc. of Automotive Engs., August, 1920.
Possible fuel savings in automotive engines (H. C. Dickinson and S. W. Sparrow), Jour. of the Soc. of Automotive Engs., January, 1921.
Automotive research with reference to fuels and lubricants, Bureau of Standards, Department of Commerce (D. R. Harper and H. C. Dickinson), Petroleum Magazine.
Elements of fuel economy (W. S. James), Jour. of the Soc. of Automotive Engs., June, 1921.

REPORTS OF THE NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

Performance of a Liberty 12 airplane engine (S. W. Sparrow).
Performance of a 300-horsepower Hispano-Suiza airplane engine (S. W. Sparrow).
Some factors of airplane engine performance (V. R. Gage).
A high-speed engine-pressure indicator of the balanced diaphragm type (H. C. Dickinson and F. B. Newell).
Turbulence in the air tubes of radiators for aircraft engines (S. R. Parsons).

TECHNICAL NOTES OF THE NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

An instrument for measuring engine clearance volumes (S. W. Sparrow).
A variable-speed fan dynamometer (Karl D. Wood).
High thermal efficiency in airplane service (S. W. Sparrow).
Increase in maximum pressures produced by preignition in internal-combustion engines (S. W. Sparrow).
Causes of cracking of ignition cables (F. B. Silsbee and J. B. Dempsey).
Plane crashes: Engine trouble. A possible explanation (S. W. Sparrow).

The following papers are in press or have been submitted for publication:

Testing of thermometers, B. S. Cir. No. 8, 3d ed.
Soft X rays from arcs in vapors (Mohler and Foote), Jour. Apt. Soc. of Am.
The excitation of the enhanced spectrum of magnesium in a low-voltage arc (Foote, Meggers, and Mohler), Phys. Rev.
Characteristic X rays from arcs in gases and vapors (Mohler and Foote), Jour. Wash. Acad. Sci.
Total heat diagrams for Ammonia (Mueller and Meyers), Jour. Am. Soc. Ref. Engs.
The specific volume of liquid ammonia (Cragoe and Harper), B. S. Sci. Paper.
The production of liquid air on a laboratory scale (Cook), B. S. Sci. Paper.
Provision in concrete construction against extreme fire conditions (Hull), Proc. Am. Concrete Inst.
Radiators for aircraft engines (Parsons and Harper), B. S. Tech. Paper.

The Mathematical theory of induced voltage in high-tension magnetos (Silsbee), B. S. Tech. Paper.
Performance of Maybach 300-horsepower airplane engine (Sparrow), Repts. Nat. Advisory Com. for Aeronautics.
Performance of B. M. W. 185-horsepower airplane engine (Sparrow), Repts. Nat. Advisory Comm. for Aeronautics.
Simplified magneto mathematics (Silsbee), Reps. Nat. Advisory Comm. for Aeronautics.

4. OPTICS.

The work of the Optical Division includes the following principal lines of activity: Spectroscopy, devoted to radiation and absorption spectra, along with certain phases of qualitative and quantitative chemical analysis for which these are especially applicaable, and the development of infra-red photography for astronomical observations and aviation purposes; polarimetry, devoted to investigations and tests involving measurements of polarized light and its application, especially in the testing, standardization, and technology of sugar, including the supervision of the sugar laboratories of the Customs Service; colorimetry, concerned with the measurement of the factors which determine color, the optical transmissive and reflective porperties of materials, and the color grading of light sources and materials; refractometry and optical instruments, interested chiefly in the performance and development of optical instruments and materials, including refractive indices and disperson measurements; radiometry, which covers the more general field of radiation, determination of the fundamental constants of radiation, the development of radiometric methods and instruments, and the determination of the emissive, reflective, and absorptive properties of materials for thermal radiation; interferometry, which makes use of the light wave as a standard unit for high-precision length measurements and develops the application of interference methods; and photographic technology, concerned with the investigation of photographic apparatus, testing of photographic materials and devices, standardization of testing methods, and general photographic investigations. It includes, also, the optical investigation and measuring of the physical properties of dispersoids, such as smoke, water supplies, etc., and investigations in cooperation with the Engineer Corps of the Army on the conditions governing searchlight illumination, with special reference to the testing and improving of searchlight mirrors and search-lamp performance.

SPECTROSCOPY.

Standard Wave Lengths.

The high precision with which the lengths of certain waves of light can be measured or compared is now more or less of a commonplace, but the importance of such measurements is ever increasing. Extensive use of standard wave lengths of light for testing the lengths of gauges, for ruling scales, and testing the constancy of such material standards are practical applications of comparatively recent origin, and the increased accuracy of all spectroscopic data based upon the international standards now makes it possible to calculate some important physical constants and to realize the significance of spectral series in connection with atomic models and radiation theory.

Since the international adoption in 1906 of the wave length (6,438.4696A) of the red radiation from cadmium as the primary standard of wave length, a considerable number of other radiations have had their wave lengths compared by interferometer methods with the primary standard, and some of these were adopted as international secondary standards. The history and present status of this subject was summarized during the past year in a Report on Standard Wave Lengths, published in the Journal of the Optical Society of America, July, 1921.

The spectra of the inert gases—helium, neon, argon, krypton, and xenon—contain radiations which are remarkably homogeneous and reproducible. The precision with which such radiations can be defined makes them valuable as wave-length standards and has theoretical importance in analyzing the structure of the spectra. In Bureau of Standards Scientific Paper No. 329 the values of 54

wave lengths in the spectrum of neon were given, and attention was called to the constancy of frequency differences among certain groups of lines. During the past year similar measurements were made on the wave lengths of 50 lines in the argon spectrum, 18 in krypton, and 12 in xenon. The values are considered to be correct in most cases to one part in several millions, and frequency differences recurring among lines in the spectra of argon and krypton were found to be constant within the limits of probable error in these wave-length measurements. The exactness of the combination principle of Ritz has thus been verified for the three elements—argon, krypton, and xenon.

In addition to these measurements of wave lengths in the spectra of gases the interferometer has been employed in further determinations of standard wave lengths in the arc spectrum of iron. The longer waves in the red and infra-red spectral regions are being compared with the primary standard, and it is planned to continue this work during the coming year.

Investigation of Arc Spectra.

Five years ago this laboratory began a program of wave-length measurements in arc spectra of the chemical elements. The object of this investigation was to describe as accurately and as completely as possible the characteristic spectra of all the chemical elements, especially in the red and infra-red spectral regions to which ordinary photographic materials are insensitive. With the aid of photographic plates stained with photosensitizing dyes the Bureau has succeeded thus far in determining standard spectra for more than half of all the known chemical elements. During the past year the results were published (Bureau of Standards Scientific Paper No. 411) for arc spectra photographed in the yellow, red, and infra-red for the following elements: Silver, gold, lead, mercury, tin, zinc, antimony, and bismuth.

In many respects the group of rare earth elements is the most interesting of all the chemical elements in the periodic system. This group contains 16 elements, with atomic numbers from 57 to 72, both inclusive, but No. 61 is still unknown. The absorption spectra of these elements in solution are marked by strong bands which are relatively narrow and unlike those of most of the other elements, while their emission spectra are extremely rich in fine lines of moderate intensity. Samples of most of the rare earths have been collected from various sources for purposes of spectral analysis and other data, the most extensive collection being that prepared in Austria by Carl Auer von Welsbach for Prof. J. M. Eder's spectroscopic investigations. Excellent samples of some of the elements were presented to this laboratory by Prof. B. S. Hopkins, of the University of Illinois, and by Prof. James, of Durham College. The first of a series of Bureau of Standards' Scientific Papers on these materials was prepared with the cooperation of the University of Illinois and is now in press. It describes the chemical separation and purification of eight elements and contains about 2,500 wave-length values in the yellow, red, and infra-red arc spectra of yttrium, lanthanum, and cerium. In addition to these results the arc spectra of neodymium, samarium, gadolinium, dysprosium, zirconium, columbium, europium, erbium,

holmium, and didymium have been carefully investigated and many thousands of wave lengths have been measured in the arc spectra of these elements.

Similar work has been begun on the arc spectra of ruthenium, rhodium, palladium, osmium, iridium, and platinum, very pure samples of which have been prepared by the Chemistry Division of this Bureau. It is hoped that the longer wave spectral regions for these so-called platinum metals as well as for the rare earths and similar elements may be completely defined within another year.

Spectroscopic Analysis.

This laboratory has been called upon during the past year to make spectroscopic analyses of more than 130 miscellaneous materials, including tool steels, rare earths, platinum metals, mint gold, thermocouple materials, storage battery materials, colored glasses, enamel, various alloys, etc. In the preparation of metals in a very high state of purity the spectroscope gives valuable assistance in detecting traces of impurities and in controlling the chemical procedure for further purification. The spectral method is in many cases more sensitive and convenient than the chemical method for detecting impurities, and for this reason it is highly desirable to study the partial spectra of elements present in mixtures, alloys, etc., to establish a quantitative basis for spectral analysis. The induction furnace has made it easy to prepare standard alloys of metals in definite proportions, and spectral examination of these shows that it is possible to make precise quantitative analyses within certain limits. The Metallurgy Division of this Bureau has prepared such standard alloys of iridium with platinum and of iron, copper, lead, and silver with gold. These impurities in the range from 1 per cent to 0.0001 per cent can be determined with dispatch and precision from an examination of the spark spectrum. It is possible for the United States Mint to adopt this method of analysis of proof gold for which the chemical and fire-assay methods are both more tedious and uncertain.

Spectrum Tubes.

Electrical discharge tubes containing pure gases are used extensively for purposes of optical testing, research, and instruction. Such tubes have been difficult to obtain in this country, and the spectroscopy section of this Bureau has been unable to supply the large demand for them. About 100 tubes containing either hydrogen, oxygen, nitrogen, helium, neon, or argon were made during the past year and furnished to research and testing laboratories, astronomical observatories, colleges, and universities.

In cooperation with a section of the Heat Division which has investigated electrical phenomena of radiation from low voltage arcs spectral analyses were made of the radiation from such sources. The single-line spectrum from magnesium vapor was photographed (Scientific Paper No. 403), and more recently the conditions necessary for the production of the two-line spectrum, the arc spectrum, and the spark spectrum of magnesium were determined from spectroscopic observations (in press). Similar work is in progress with other metals, various spectra of cadmium, sodium, and potassium

having been photographed thus far. This investigation gives important information on atomic structure and on the mechanism of radiation.

Photosensitizing and Hypersensitizing.

The great need for specially sensitive photographic plates for spectroscopic investigations led to experiments in photosensitizing and hypersensitizing which have resulted in photographic materials far superior to any obtainable on the market. The chief object has been to increase the sensitiveness of photographic emulsions to red and infra-red light. The success with which such emulsions have been prepared and applied to spectroscopic investigations, to long-range ground photography and aerial photography for haze penetration, and the possibility of using red sensitive emulsions for daylight photography of stars, all these are factors which urged the continuation of experiments to develop certain characteristics of photographic materials.

During the past year, accordingly, further studies have been made in (1) color sensitizing ordinary emulsions by bathing in solutions of photosensitizing dyes, and (2) hypersensitizing commercial panchromatic emulsions with ammonia or water. In cooperation with the photographic laboratory quantitative measurements of the speeds, filter factors, etc., have been made with these specially treated emulsions and some interesting and important information obtained on the relative values of different methods of treatment as regards spectral sensitivity, total speed, keeping qualties, fog, etc. These results will appear in a Bureau of Standards Scientific Paper.

POLARIMETRY.

Polarimetric Work.

In the previous report there was stated the fields of endeavor in which the greatest demands were being made upon the Bureau for assistance and the necessity for meeting these demands as far as available funds and equipment would permit. Attention was directed to the increasing demand for the standardization of methods of analysis, the standardization of technological processes, and for accurate data on the fundamental constants of the sugars and their associated products. The results which have been attained in meeting these demands have been gratifying. By rearrangement of space already utilized for other work suitable temporary quarters have been found and apparatus and equipment installed to permit of investigational and standardization work in the new fields. As a result the Bureau now has new laboratories, fairly well equipped, devoted to the rare sugars, their production, and the determination of their physical and chemical properties; molasses and sirups, and sugar testing; the study and standardization of quartz control plates; the measurement and study of double refraction; the standardization of saccharimeters; the standardization of decolorizing agents, including vegetable carbons and inert materials.

In addition to the above two complete plants for the study of the standardization of technological processes in sugar manufacture are in process of installation. The larger of these will permit of experimental work with quantities of raw material weighing several

hundred pounds. The smaller is an exceedingly flexible plant, involving every step utilized in modern sugar factories, but carried out on a laboratory scale so as to make possible preliminary work with only a few pounds of raw material. The results obtained through the utilization of the small laboratory plant can be verified on a near factory scale by the use of the larger plant. It is apparent that the derived results will by this means be thoroughly tried out and verified before application is attempted in the large sugar factories throughout the country. Experimentation in the factories is always difficult and expensive and interferes with the conduct of the business of the particular factory which is being utilized. It is thus obvious that the Bureau will make every effort to establish the complete success of the standardization of a process before it is even experimented upon in actual factory operations. The work of designing and successfully building the large number of units for these experimental plants is obviously difficult and slow. Sufficient progress, however, has been made to enable a partial, if not full, utilization of these plants during the current year.

Standardization of Sugar Manufacture.

The present period of readjustment is a trying one for the sugar industry. The economic need of research and specifications for the standardization of methods of manufacture of sugar is being felt more keenly than ever, especially by that portion of the industry which, for various reasons, has never had recourse to any well-planned research and other study of its problems. In spite of increased need for such service the research departments of the larger manufacturers will almost inevitably be affected by the general spirit of retrenchment which must accompany the readjustment. With these facts in view the Bureau has outlined and begun research along certain lines which should prove of general assistance.

The Rare Sugars.

The sugar group includes a large number of substances which are very widely distributed in nature and which, from many points of view, are becoming more and more important. While many members of the group occur free in various plant and animal products, others are constituents of more complex compounds, and some, so far as is known, do not exist naturally. These latter compounds are only obtained by synthetic methods in the laboratory.

At the present time the most important use for these substances is in pathology. By means of certain sugars or their derivatives, such as the corresponding alcohols, certain pathogenic organisms may be identified or closely related species may be differentiated. For this purpose the compounds must be of the highest attainable degree of purity.

Their preparation in this condition is often associated with considerable difficulty, and therefore requires the skill of an expert. It is for this reason, and also the fact that the work is only in the pioneer stages, often lacking the most fundamental data, that the market prices are extremely high, ranging from $10 to $500 per pound. This naturally restricts their use. It is, nevertheless, noteworthy that whereas up to the time of our entry into the war all

these substances were obtained from Germany, now American manufacturers are producing a number of these sugars and sugar derivatives in a state of purity and at a price comparable with those existing before the war. However, there is vast room for improvement, not only in respect to their purity and availability at greatly reduced prices, but also in the production of a large number of these substances that are as yet unavailable and which could undoubtedly be of great assistance to and simplify the work of the pathologist.

While the above-mentioned application of the rare sugars at the present time is perhaps the most important, other factors regarding them are nevertheless to be considered. It is only by means of a systematic study of the whole group that any degree of progress can be made in the individual cases.

In order to assist the industries immediately interested in this group of compounds and to assist the medical profession by making the sugars more available at a much reduced price and in a higher state of purity and to contribute to the knowledge of the sugar group itself, a section has been developed for the study of the rare sugars. The work has already met with considerable success.

The first half of the year was devoted to equipping a laboratory, obtaining the necessary apparatus, and getting it into operation. The remainder of the year was spent in making various compounds to be used as starting material for various problems that are in progress. These problems are especially directed toward obtaining the sugars in the highest possible state of purity and the determination of their physical constants, especially their specific rotation, with the utmost degree of accuracy. This will enable all workers to have a standard of purity by which to judge their results. The meager data which are now in existence on this subject are wholly inadequate to meet the demands for even commercial manufacturing operations.

As a concrete result of the Bureau's efforts in this field convenient and economical methods have already been perfected for preparing three of the rare sugars, namely, raffinose, galactose, and mannite.

Polarimetry of Oils.

Many oils, whether of the mineral, fatty, or essential classes, are naturally active; that is, they rotate plane polarized light to a greater or less degree, and all become active or doubly refracting in varying degrees when placed in a magnetic or electric field. Measurements on these properties make it possible to identify oils, to detect adulteration, and in many cases to determine their composition and molecular structure. Data of this sort obtained on oils used in foods, drugs, fuels, paints, etc., have great commercial value. During the year progress has been made in collecting such data and in devising better methods of making the required tests, especially in regard to the measurements on the electric double refraction.

Quartz Control Plates.

A plate of crystalline quartz, cut perpendicular to the crystallographic or optic axis, has the power of rotating the plane of polarization of a beam of plane polarized light in the same manner as a sugar solution. Advantage has been taken of this fortunate circumstance to provide a positive and unchangeable device in the form of

the quartz control plate for checking the accuracy of saccharimeters. The saccharimeter, being a very complicated and delicate piece of apparatus, may easily get out of adjustment, thereby rendering uncertain the test of a sugar. Every inaccuracy due to this condition is wholly avoided by placing a control plate in the instrument and comparing the reading obtained with the standard value of the plate. These plates are thus of fundamental importance throughout the sugar industry and in scientific laboratories as well. During the year 142 of these plates were tested, 131 of which were American-made plates. Twelve were rejected as being unfit for precise saccharimetric work, either because of inhomogeneity of the quartz or because of improper mounting.

With the idea of being of the greatest possible assistance to the sugar industry, the Bureau has continued its policy of remounting and testing improperly mounted plates when they are already in the possession of the industry, but rejects them when they are submitted for test by the makers. This serves to make reliable many plates which would otherwise be unfit for accurate work and in a measure to prevent unfit plates from reaching the industry. On account of the fact that a number of firms here and abroad have undertaken the manufacture of quartz control plates, it has become more than ever necessary that all such plates be critically examined for defects. To aid in accomplishing this, the apparatus previously utilized for testing the degree of planeness and parallelism of the plate and the so-called "axis error" has been improved. These tests, together with a critical examination of the mounting of the plate, are made in addition to the usual tests of homogeneity and sensitiveness in the polariscope and the precise determination of the sugar value of the plate.

The Bureau has been of considerable assistance to manufacturers of quartz control plates and through them to the sugar industry as a whole by testing their plates, pointing out defects, and indicating what points should be given more attention. A marked improvement in the quality of the plates has resulted. First-class quartz control plates of American manufacture are now available.

"Reaction" of Sugar Products.

By "reaction" is meant the degree of acidity or alkalinity of a product. In the previous year, by means of a recently developed series of indicators, the reactions of a large number of granulated sugars of commerce were determined. The experience acquired in this work has been utilized in other applications, with the result that the control of acidity and alkalinity appears to have a far more extended application than was at first supposed. The colors of impure products and the decolorization by means of charcoal is apparently strongly influenced by the reaction of the solution. It has recently developed that the flavor of a sugar sirup is much improved by bringing it closely to a neutral reaction as shown by these indicators. In some instances flocculation of contaminating colloidal impurities is aided by adjusting to a proper reaction. The applications appear so extensive that further investigation by indicators and by electrical methods has been planned.

100° Point of the Saccharimeter Scale.

Owing to the abnormal world-wide conditions now existing in the sugar industry, the basis of standardization of the saccharimeter has taken on an added significance, and the necessity for international agreement as to the value of the 100° point is greater than ever. The Bureau has made continuous efforts looking to a solution of this difficulty. These efforts have finally culminated in some prospects for success. The proper authorities in Germany have entered into negotiations with the Bureau regarding this matter, and a 100° sugar quartz control plate has been forwarded to the Imperial Sugar Institute in Berlin. In the meantime the Bureau's correct value for the 100° point has become nearly universally adopted throughout North America. The new and largely increased tariff on sugar now in effect has doubled the importance of the Bureau's discovery of an error of over one-tenth of 1 per cent in the old value of the 100° point. The saving to the Government resulting from this work now approximates $150,000 per annum.

Cooperation with Customs Laboratories.

The work incidental to assisting the Treasury Department in the maintenance and operation of its customs laboratories has been continued with excellent results. Heavy importations of sugar have necessarily created much additional work for the Bureau. It was found that the facilities were inadequate for this work and the carrying on of the control analysis of raw sugars. Additional space was obtained and the new laboratory equipped to expedite this work. During the year 1,570 exchange samples of raw sugar were tested. Approximately 50 per cent were direct polariscopic determinations for the quantity of sucrose present, and the remainder were tested for the percentage of moisture in addition to sucrose content.

Grading of Commercial Sugars.

Laboratory work on the investigation looking to the preparation of standard definitions and specifications for direct consumption sugars has been practically completed. Grave difficulty has been experienced in making practical application of the facts derived from these data. A careful study of the manufacturing conditions under which many of the sugars are used has been found necessary, and the preparation of definitions requires a comprehensive study of the average practice throughout the country in the utilization of refined sugars. The necessary information must be obtained from many individuals who have had years of practical experience in the manufacture and grading of these products.

Color of Sugar and Sirups.

The investigation of this subject is now well under way. It is connected very closely with the problem of standardizing decolorizing agents, which has been discussed under that heading. In the problem of determining the color of sugar products the Bureau has been greatly aided by the active cooperation of a number of the large refineries. They have painstakingly prepared and forwarded a great number of representative refinery liquors, and the work is

being extended to cover all grades of liquors produced in factories as well as refineries. The technical colorimeters commonly in use have proven wholly inadequate to meet the needs of the work, and far more sensitive and accurate methods, which are available only in an institution such as the Bureau of Standards, have been utilized. It was found that a less accurate procedure would not give the necessary facts, owing to the necessity for determining the absorption of these liquors for the different wave lengths of light. Excellent progress has been made in measuring these absorptions for all classes of sugar products, ranging from molasses to the almost colorless grades of granulated sugars. When the work is completed, it will be possible to clearly define the outstanding characteristic color phenomena of each class. It is expected that this, in turn, will lead to an adaptation of the facts to the small, simpler needs of a large variety of manufacturers. The work of standardization of colorimetric practice for the sugar industry, therefore, concerns itself not only with the mode of analytical preparation of sugar products—a factor of far greater influence than heretofore thought possible—but also with the manner of calculating the results to a common unit basis, employing different makes of commercial colorimeters. The results thus far obtained indicate that it will be possible to create a solid scientific basis for colorimetric practice, thereby making possible a more scientific colorimetric practice in the industry, using technical commercial instruments.

Preparation of Levulose.

Levulose is the sweetest member of the sugar group and is wholesome for human consumption. It is very widely and abundantly distributed in plants that are capable of extensive agricultural development. It occurs, for example, in the form of a starch called "inulin" in the roots of the dahlia and the Jerusalem artichoke, both of which may be grown extensively. Owing to the peculiar properties of the sugar—its great tendency to suffer decomposition and its extremely high solubility—its extraction affords a problem of such difficulty that pure levulose is one of the most costly sugars.

In the previous year experiments were made on the extraction from invert sugar. During the past year the extraction of inulin from plants and its conversion to levulose has been studied. These experiments have shown that levulose may be prepared at a considerably reduced cost, and that the material should readily become available for scientific and bacteriological work.

Clerget Analysis for Sucrose.

In a paper entitled "The Double Polarization Method for Estimation of Sucrose" the Bureau made public a series of modified Clerget methods for the analysis of sucrose in mixtures, which make possible an exact analysis in the presence of disturbing impurities. These methods have already found application in the sugar industry.

Certain criticisms have, however, appeared in the current literature. If valid, they would have lessened the high degree of precision originally claimed for the methods. These criticisms led to an extensive and minute examination of the fundamental principles upon which the method were based. In every instance the basic principles were found to be sound. This conclusion was reached not

only from the Bureau's experiments, but was also established from outside independent experimental data. The discussion has furnished an important contribution toward placing the Clerget procedure among the exact methods of analysis.

Raffinose in Beet-Sugar Products.

Raffinose, a sugar, occurs as an impurity in beet-sugar products. Its analysis is therefore a question of great importance. In the presence of sucrose it may be determined with sufficient accuracy by means of the usual Clerget method. The latter, however, is strictly applicable only in the absence of other optically active impurities. The products of the beet-sugar house contain unknown optically active substances which vitiate the accuracy of the method. As the method is now used, all these substances are grouped together and are designated "raffinose." Not only is the estimation of true raffinose incorrect, but certain errors are introduced in the analysis of sucrose. This problem, in spite of extensive investigation, has proved a very baffling question. A research is now being carried out by the Bureau to find some selected property by which true raffinose may be determined. While the results obtained thus far are not wholly negative, much further study will be required to obtain a satisfactory solution of the problem.

In addition to the search for a distinguishing property of raffinose in mixtures the preparation and optical rotation of the pure substance in solution have been studied in a preliminary manner.

Testing of Molasses.

The Bureau continued to act as referee between buyers and sellers in the polariscopic analysis of molasses. Since a large proportion of the molasses for manufacturing purposes is bought on the basis of total sugar content and density, a number of manufacturers specify that settlement be made on the Bureau's analysis. During the year 45 samples were analyzed. The Bureau's value of the Clerget divisor has been adopted as a standard in the estimation of sucrose. A study of a number of new methods of determining the amounts of reducing sugars present in molasses is being made with the view of increasing the precision of this determination. The investigation of the methods of determining density has been continued, and the results are now being tabulated. A modified form of picnometer for density determinations in this work has been designed and is being used in referee testing of molasses and sirups.

The Bureau was requested by an association of cracker manufacturers to cooperate with them in an effort to establish specifications for molasses. In this connection 10 representative samples of molasses were submitted by this association for test and a large volume of analytical data was obtained. As a result of the investigations of both the association and the Bureau the former has issued a comprehensive bulletin on the subject to its members. From the results obtained in the research to secure a stable sirup of maximum density it was possible to predict from the composition of a molasses whether sugar would eventually crystallize out. From the same investigation a method of preparing a sirup of stable composition was developed.

Beverage Sirups.

Assistance along lines similar to that discussed under the subject of the testing of molasses was given manufacturers of beverages. Wide diversity of procedure in the production of these sirups was found, and practically all producers experience difficulty in preparing a satisfactory sirup. A number of sirups were made according to practical formulæ and analyzed. The indications now are that methods devised by this Bureau will produce a sirup whose composition and properties will make it more suitable for beverage purposes. The entire subject of specifications for molasses and sirups is still under investigation.

Molasses Formation.

Owing to lack of facilities much of the specific work needed on this problem could not be carried out. Most of the apparatus necessary has been acquired and nearly erected. It is hoped that the much-needed definite results will soon be obtained. A considerable amount of valuable preliminary experimental work has been carried out.

Decolorizing Agents.

For several years communications have been received at frequent intervals from various industries requesting information on the decolorizing power of various carbons, bone black, and other decolorizing agents. The use of these materials has greatly increased in the last decade until they have become an indispensable part of the manufacturing processes in many industries. This growth has come about despite the fact that there has been no adequate method of standardization or system by which their performance for a particular purpose could be gauged. The need for a method of standardizing and grading the decolorization agents has been noticeable in the sugar industry. An extended investigation and study of the subject has therefore been undertaken with particular reference to the requirements of the industry in order to secure the necessary data for defining a method of standardization with regard to performance for all uses for which decolorizing agents are applicable.

A large number of decolorizing agents have accordingly been collected with the object of studying their application to the problem of decolorization of impure sugar liquors. The materials so far used are samples of imported sugar as well as those produced by domestic refineries.

The analytical preparation of these sugars necessarily includes a study of the effect by the so-called affination process. This process aims at a preliminary refining of the raw-sugar crystals by mingling them with concentrated sugar sirup, which is then swung off in the centrifugal, removing thereby the greatest part of the coloring substances with the machine sirups. The sugar crystals remaining in the centrifugal basket are the so-called affined sugar, containing now only a small amount of coloring matter. Decolorization is therefore being studied on liquors which are produced in the laboratory by close imitation of actual factory methods and practice.

The degree of decolorization is being ascertained by precision methods, using an optical instrument known as a spectro-photom-

eter. The sensitiveness of this instrument has revealed the urgent necessity of standardizing and placing upon a solid scientific basis the analytical preparation of impure sugar liquors for colorimetric analysis.

How urgent the standardization of this analyticaal preparation of the liquors for colorimetric analysis really is will be appreciated from the discovery that all filter aids—i. e., inert material, such as filter-cel, kieselguhr, talcum, magnesium, carbonate, etc.—exercise a selective absorption, while all filter-paper filtrates are unsatisfactory on account of variation in pore size and the presence of loose fibers. A further discovery has been made that the highest grade long-fibered asbestos used as a filtering medium will deliver an acceptable quality of filtrate.

A comparative study of the method of analysis described above with other methods of preparation is now under way. It has been found necessary to study the various methods of ultra filtration, the object of which is to produce a so-called optical void or absolutely clear liquid. No way could be found to obviate this extensive work, as it is necessary to define the limits of accuracy of the unsatisfactory methods which have long been used in the technical colorimetry of sugar products which were developed without the present-day knowledge of colloidal chemistry. The entry of decolorizing carbons into industrial sugar manufacturing has developed the fact that there is in existence at present no laboratory technique which can cope with the manifold difficulties which develop when sugar solutions are exposed to the decolorizing action of carbons or which are inherent in the nature of viscous impure solution.

In view of these facts which this important investigation has so far brought out, it is obvious why great difficulty has been experienced in industrial processes in the proper use of decolorizing agents, and in view of the difficulties of developing a proper laboratory technique it is no longer surprising that so little progress has been made in solving this problem. The results so far obtained in this work lead to the expectation that a satisfactory solution of the problem of standardizing and grading decolorizing agents will be attained.

The Laboratories for Sugar Technology.

During the year these laboratories have acquired more adequate quarters, consisting of three large rooms, with the temporary use of a fourth. Two of these rooms are equipped as laboratories for the chemical and physical measurements and the clerical work and supervision involved. The third is nearly equipped as a pilot laboratory, the various parts or stations of which are very flexibly coordinated, so that the plant is readily adaptable to many different problems. It is capable of being quickly converted from one type of work to another, both as to kind of operations and as to their sequence. For the fourth laboratory a plant of semicommercial size has been designed. The apparatus so far obtained consists mainly of what the sugar engineer terms "sugar-end" equipment, in some cases single units of full-sized apparatus and in other cases apparatus of semicommercial size, specially designed for precise work.

Several manufacturers have very kindly loaned part of the apparatus for the pilot laboratory and offered assistance of various kinds in equipping the semicommercial plant.

Special Apparatus and Construction.

In order to carry on with the requisite precision the work on several of the problems in sugar manufacture it has been found necessary to employ new apparatus specially designed for the purpose. Some of these designs have originated outside the Bureau, but a large proportion of them have been made here, occupying a considerable part of the time of the laboratories of sugar technology. Whether originating outside or in the Bureau, however, nearly all of these designs are the work of the present Bureau staff.

Gradation of Sugars by Sieve Analysis.

The importance of this undertaking was discussed briefly in last year's report. The preliminary work is complete, and it is hoped that a representative committee may be formed during the coming year to pass upon specifications which will be proposed.

Diffusion Process in Sugar Manufacture.

It was found impossible to continue active work on the diffusion process, important as it is, especially to the beet-sugar industry. The year's work, however, indicates that the process has a broad field of application, and a special battery has been sketched for use in the rare sugar and related industries.

Storage and Shipment of Sugar.

The problems naturally falling under this heading are of great economic importance to every interest involved, and yet apparently it has not been the subject of much well-planned research. Most of what has been established relates especially to raw sugar. The caking of white, dry granulated sugar during storage and shipment has been studied more or less extensively and with varying degrees of success by several of the leading producers, but there is still a considerable question as to the best system of handling under the various conditions commercially encountered. The Bureau has studied and recalculated data obtained by one of these producers in its laboratories and warehouses. This work is preliminary to a complete study with more refined technique, which the Bureau is undertaking.

Production of Mannite.

Owing to the Bureau's previous development of a method of producing d-mannite of high purity in considerable quantities for the War Department, it has been possible to take up the important scientific problem of determining the physical constants of this rare sugar. A quantity of the material has been purified in the laboratory to a very high degree and a number of measurements on the specific rotation made. Experience has shown that the Bureau can perform no greater service in this field than to leave a permanent record in the form of the exact values of the physical constants of rare substances. Such data are not now in existence.

Crystallization.

The general problem of crystallization has come to be an important one in many industrial fields of endeavor. Its largest application is found throughout the sugar industry where a process of fractional crystallization is utilized. The problems to be solved are largely of the same nature, regardless of the commodity produced, whether they be high-grade chemicals or new materials developed in the Bureau's investigational work. The field is so broad that only an entering wedge has thus far been made in the Bureau's investigation. Delicate control apparatus has been designed and placed in operation for the growing of crystals, and for the study of fractional crystallization special apparatus has been designed and erected.

Composition of Sirups of High Density.

The investigation of the composition and preparation of sirups of high sugar content, of which a preliminary report was made the previous year, has been brought to completion. A considerable portion of the sugar produced in this country is utilized in the form of sirups. The necessity for specific information as to the best method of preparation of these sirups for definite purposes has long been recognized, and the problem of producing them in a stable form has been a fundamental one in the sugar industry.

A saturated solution of pure cane sugar contains but 68 per cent of sugar. Such a solution is too dilute for a useful commodity. If, however, the sugar is partially inverted, thereby forming the mixture of dextrose and levulose, known as "invert sugar," the content in total sugars may be considerably increased without resulting in a crystallization or "sugaring out." The investigation has disclosed that if the solution contains 33.6 per cent of sugar and 45.4 per cent of invert sugar the total solids may be increased to 79 per cent without danger of crystallization. A calculation has shown that after this process a given quantity of water is capable of dissolving 75 per cent more total sugar after this partial inversion than it did before.

For many purposes so dense a sirup is not required. The investigation has shown that for lesser concentrations greater tolerances are permissible. For example, if the sirup is to contain but 74 per cent of total sugar, any degree of inversion between 34 per cent and 79 per cent will yield a sirup which is perfectly stable.

A completely inverted sugar sirup is used extensively in the industries. The research has shown how such a sirup may be readily and cheaply prepared and how great its density may be without a resulting crystallization. If invert sugar is concentrated above 69 per cent, dextrose separates in small crystals.

These conclusions have been based on a systematic study of the solubilities of the various sugars in the presence of each other. In this study the principles of the phase rule have been applied.

A table of densities of pure invert sugar solutions, extending from 6 per cent to 70 per cent, has been computed and the magnitudes of the corrections, which must be applied to the Brix hydrometer reading, have been tabulated.

Solubilities of Dextrose.

The development of the commercial process of manufacturing pure crystalline dextrose requires a knowledge of the solubilities of the sugar over a wide range of temperature.

Thus, as a fundamental basis for calculating supersaturation coefficients, for estimating crystallizer performance, and for the more extended investigation of the effects of nonsugars on the process of crystallization, the solubilities assume a technical as well as scientific importance.

This investigation has been brought to completion during the current year. A complete series of determinations of the solubilities, extending from −5° C. to 90° C., have been made. The saturated dextrose solution depresses the freezing point of water to −5°. From this temperature to that of 50° C. the stable form of crystalline dextrose contains 1 molecule of water of crystallization; i. e., the pure solid crystal contains about 9 per cent of water. At 50° there occurs an abrupt transition, and above this temperature the stable form of dextrose is completely anhydrous; i. e., it contains no water of crystallization. Under certain conditions, however, this anhydrous form may be made to crystallize from water solutions at temperatures much below 50°. The curve representing these solubilities has been extended even down to 28° C. In the upper ranges the curve has been extended to 90° C.

Candy Test for Sugar.

There have long been conflicting ideas regarding the suitableness and applicability of certain refined sugars for the making of candy. That there is some justification for the ideas concerning the variability of their suitableness has been established. The problem has been attacked by the Bureau in connection with the analytical study of refined sugars. A definite result has been attained in the development of a candy test showing a higher degree of precision and indicating the presence of minute quantities of impurities which vitally affect the quality of the product obtained when the sugar is used in the confectionery industry. A new precision apparatus has been designed for this work, and it is believed that additional information needed to carry this investigation to a successful conclusion will be obtained.

Baumé Scale.

The standard Baumé scale for liquids heavier than water, perfected by the Bureau, has now practically displaced all other Baumé scales for scientific and industrial purposes. Scientific opinion seems divided as to how far the Baumé principle should be utilized in the sugar industry. The plan adopted in the new table, of giving the Baumé value opposite the corresponding value in percentage of sugar or degrees Brix, has given excellent results. The use of the more expressive and significant value in percentages of sugar has greatly increased.

Supplies for the Customs Service.

In view of the fact that many of the supplies as well as equipment used in the laboratories of the Customs Service are purchased under the rigid specifications of the Bureau of Standards and are neces-

sarily sent to the Bureau for test, a storeroom was set aside last year in which a supply of these materials may be held ready for shipment. A sudden demand for these materials by any port may now be met without delay. A number of additional items have been added to the stock, and at present a supply of such apparatus as volumetric flasks, polariscope tubes, cover glasses, dichromate absorption cells, thermometers, picnometers, pipettes, etc., is kept on hand. The improved service in securing laboratory supplies which must be accurately tested has been of material benefit to the entire Customs Service. For some years it has been practically impossible to secure delivery of volumetric apparatus within any reasonable time limit, and as emergencies are continually arising in the Customs Service in which these materials are needed, great embarrassment in expediting the delivery of merchandise to the customs ports has frequently resulted.

A suitable supply of sugar weights, as well as sets of analytical weights, is being accumulated as rapidly as possible. It is a matter of importance that the weights in use at the customs ports be returned to the Bureau at frequent intervals for testing. This can be made possible only by establishing a suitable reserve supply, to be held at the Bureau. Increased precision in the work of appraisal in the Customs Service will necessarily result from this procedure.

The idea has long been prevalent that the polariscope tube, once it has been accurately adjusted for length, would remain so. In an investigation of certain discrepancies appearing in the work at various ports the Bureau discovered that because of the continuous service demanded of these tubes the length determinations could not be depended upon for more than a year. A sufficient number of tested polariscope tubes is now kept on hand at the Bureau and it is possible to have the tubes in use at the customs laboratories replaced at frequent intervals and the old tubes returned to the Bureau for test. Where inaccuracies exist the tubes are sent to the manufacturer for readjustment. This procedure has resulted in the saving of a considerable sum annually to the Treasury Department. In the development of this work, and especially in the securing of increased accuracy which is essential in the collection of the customs revenues, the Bureau has had the encouragement and assistance of the officials of the Treasury Department.

Properties of Quartz at High Temperatures.

The investigation of the physical properties of quartz at high temperatures has been continued. This includes the precise measurement of the natural rotation of light by the crystalline material at temperatures ranging from 20° C. to 1,500° C., and includes a careful exploration of the range where quartz recrystallizes and assumes new crystallographic axes. The investigation of all the physical properties of quartz is of importance from a general scientific standpoint, both because of its bearing on the problems of geology and because of its widespread utility in the scientific field in general. It is of especial interest here because of the fact that the modern saccharimeter is based upon the use of quartz in its construction. A considerable amount of computation has been completed and the data carefully studied.

Adjustment and Standardization of Polariscopes.

The work of adjusting and standardizing polariscopes and saccharimeters has been continued with gratifying results. It has been necessary to continue the work of adjusting instruments in addition to standardizing them, as few instruments reach the Bureau in perfect adjustment. The sugar industry, as well as educational and research institutions, have been unable for some years to obtain an adequate supply of new polariscopes. Several excellent types of instruments have been on the market for a year or more, but in limited quantities. Many of the instruments sent in for adjustment are of old types, having a different basis of calibration from the newer types. The Bureau has been constantly consulted in regard to the use of these instruments and has been able to render valuable service. In connection with the work of adjusting instruments a number of related problems have been solved which promise to be of value to manufacturers. Among them may be mentioned the preparation of a suitable cement for polarizing prisms and a process of grinding and polishing the faces of damaged prisms. The Bureau's facilities have been severely taxed to handle all the instruments submitted, despite the additional facilities which were provided. During the year 73 polariscopes and saccharimeters were adjusted and standardized. After adjustment the scales of all polariscopes submitted were carefully compared with the official standards of the Bureau and certificates issued, showing the corrections necessary to be applied to the scale reading to give the true rotation in sugar degrees, based on the now widely accepted Bureau of Standards determination of the 100° point of the international sugar scale.

Rotation Dispersion of Sugars.

The natural rotation of the plane of polarization of light is one of the characteristic physical properties of so-called optically active substances. The literature in this important field is meager and, in general, the work that has been done is usually lacking in precision and in nearly every case is referred to a single wave length of light, namely, sodium yellow. The Bureau has shown that the green line of the mercury spectrum is far superior to the sodium line and is coming into more and more general use. All the rotation constants will be determined for this wave length. The very important rotation dispersion constants for various wave lengths of light have been almost entirely overlooked.

In continuing this research measurements have been made to determine the rotation dispersion, using solutions of various sugars. Thus far preliminary measurements only have been made on sucrose, dextrose, and galactose. One of the principal purposes of this investigation is to accurately measure and record the characteristic physical constants for the various sugars which are now being produced by the Bureau in a high state of purity. When this has been accomplished, manufacturers and investigators will have a definite guide for the purity of their products.

The rotation dispersion was also measured for two submitted samples of abietic acid obtained from white resin. The constants were desired for coordination with the other physical and chemical properties of this substance.

Saccharimeter Light Filters.

A further investigation of suitable light filters for saccharimeters has been made. The standard filter adopted by the International Sugar Commission is a layer 1.5 centimeters thick of a 6 per cent potassium bichromate solution. As pointed out in the previous report, this filter has the disadvantages inherent in a solution. A decided improvement would be accomplished if a permanent filter, such as a colored glass, could be used in place of the solution.

The spectral transmissions of a number of colored glasses from several sources have been determined, and a glass has been found whose spectral transmission curve very closely approximates that of the standard bichromate solution. The readings obtained on the saccharimeter with a near normal sugar solution with this glass, and also with a number of others having slightly different transmission curves, have been compared to the readings obtained, using the standard bichromate filter. The observations so far obtained indicate that there is no difference between the readings obtained with a standard bichromate filter and those obtained with a glass whose spectral transmission curve closely approximates that of the standard filter. However, the differences sought after are extremely small, and no definite conclusions can be drawn until a large number of observations have been made by several observers.

The question of a light filter for saccharimeters is an important one, and no change will be recommended until conclusive experimental data are obtained.

Standard Samples.

During the past year 88 samples of sucrose and 31 samples of dextrose were distributed. These materials were principally for industrial and scientific purposes. In view of the increased demand for these materials, both in the laboratories of the Bureau and elsewhere, equipment with larger capacity is being installed. Similar equipment was studied in commercial operation, and from the information obtained a plant has been designed and ordered which will permit of great flexibility. It will make possible the preparation of considerable quantities of the various sugars. The equipment will consist of a 10-gallon vacuum pan, with condenser, receivers, vacuum pump, and complete accessories.

Tests on Cover Glasses for Polariscope Tubes.

As a result of the Bureau's work in encouraging the production of polariscope tube cover glasses in America the Customs Service and the sugar industry generally are now wholly independent of the European supply. It is essential that these glasses be very clear and as nearly free from strain as it is possible to make them. The fulfillment of the latter condition caused the German-made cover glass to be very much in demand in the United States for many years. During the past year large numbers of these glasses were tested for optical homogeneity and absence of optical activity, and it has been very satisfactory to note that practically all of them were of American manufacture.

Investigation of Strains in Glass by Polariscopic Methods.

Glass, when strained through improper annealing or by the application of an external force, becomes inhomogeneous. This condition results in variations in the density and refractive index throughout the specimen, rendering it unfit for optical purposes. To a great extent such inhomogeneities in insufficiently annealed glass arise from the existence of regions of compression and tension. These stresses result from deformations due to a lack of intemperate uniformity in the glass, either while it is being made in the required form or while it is being annealed.

The only practical method of testing glass for the presence of these inhomogeneities and the accompanying variations in the index is to examine it in polarized light and to determine to what degree it is doubly refracting. To render these tests of practical value it is necessary to know the relation of the double refraction and the variations in the index to the stresses producing them. This relation varies widely with different glasses, making it necessary to investigate each glass individually. Furthermore, since it is practically impossible to remove all the compressions and tensions from the glass by annealing it is necessary to determine the effect of their magnitude and distribution on the performance of the glass when used in optical instruments. These questions are being investigated in order to obtain data which will be available in establishing standards for the fitness of glass for optical purposes. A paper on various phases of this subject is now being prepared.

Thermal Properties of Glass.

In the region where glass loses its viscosity and becomes practically rigid it is found that there is an excessive evolution of heat in the glass on cooling. On heating through the same region there is an abnormal absorption of heat. The character of these phenomena is altered considerably by the previous treatment of the glass, whether chilling or annealing. In many respects their character suggests that in certain temperature ranges some molecular transformation normally takes place in glass which can be suppressed by rapid cooling. This effect may account for some of the variations in the refractive index in an insufficiently annealed glass. For this reason a thorough study of the effect of rapid cooling on the character of this transformation is of extreme importance in annealing, especially since it has been found that a determination of the temperature at which the heat absorption of glass occurs aids considerably in the problem of determining the proper temperature for annealing. A thorough investigation of this effect is now in progress and certain phases of it have been discussed in an article entitled "Absorption of heat in glass," published in the Journal of the Optical Society, volume 4, page 340. Additional data on this subject will soon be ready for distribution.

Annealing of Glass.

Nearly all types of glass must be annealed in order to remove objectionable strains acquired in their manufacture. In annealing optical glass the requirements are exceptionally rigid. For common glass, however, the annealing need only be sufficient to prevent it

from breaking spontaneously or in normal use. In order, however, to anneal the common glasses as easily and economically as possible, it is necessary to know the annealing temperatures, the minimum uniformity of temperature allowable, the time required for annealing, and the permissible maximum rate of cooling for each type of glass.

Investigations are accordingly now being carried out by the polarimetric section in cooperation with the pyrometry and optical glass sections of this Bureau to secure the necessary data on all the factors which enter into the annealing of common as well as optical glasses.

Hardened Glass.

In hardening glass the process followed is practically the opposite of that in annealing. In annealing glass the object is to eliminate as far as possible all strain, while in hardening glass the purpose is to introduce certain strains properly distributed. Glass so hardened has been found to be of value in the manufacture of protective goggles, windows, etc., where great resistance to mechanical shock is required. Investigations as to the relative efficiency of the various methods of hardening glass and of testing such glass have been begun.

Refractometer in Sugar Analysis.

It has been found that the refractive index of a sugar solution gives a very close indication of its total solid content, even when the dissolved solids do not consist exclusively of sugar.

At a meeting of the American Chemical Society a committee was appointed to investigate, in conjunction with the Bureau of Standards, the technical uses and limitations of the refractometer as applied to the sugar and glucose industries. A member of this Bureau was made chairman of this committee. The investigation necessitates the preparation of pure sucrose, dextrose (the methods for which have already been completed), maltose, levulose, and invert sugar, the preparation of their solutions in exactly known concentration, and a determination of their respective refractive indices with the highest possible precision.

On completion of this fundamental work the influence of impurities must be studied, and, if possible, corrections must be applied to eliminate errors. The practical value of this research lies in the fact that the refractometric estimation, once the fundamental values are ascertained, can be carried out very simply and rapidly.

Commercial Production of Pure Dextrose.

In the previous report there were given the results of the Bureau's investigation to assist in the development of a method of producing pure dextrose or glucose on a manufacturing scale. After the successful completion of the laboratory experiments and the carrying out of experimental work for a large glucose factory by a representative of the Bureau an extensive experimental plant was designed, with the Bureau's assistance, for a large corporation specializing in glucose products. The plant has been completed and successfully operated, with the result that the corporation is now completing a plant at Chicago, costing approximately $1,500,000, for the manufac-

ture of practically chemically pure dextrose. The methods and machinery used in the manufacture of granulated sugar are largely utilized, with the result that the dextrose crystallizes out in beautiful small white crystals.

Cadmium Vapor Arc Lamp.

The new cadmium vapor arc lamp developed by the Bureau as a source of monochromatic light for polarimetry has not come into general use owing to the scarcity of the element gallium. This element is indispensable in the manufacture of the lamp. A number of requests for lamps for research work have been received from European sources.

Society of Sugar Chemists and Technologists.

The efforts of the Bureau to render assistance in the formation of an American Society of Sugar Chemists and Technologists have been chronicled in a previous report. The growth of this organization and the interest manifested by all phases of the sugar industry has surpassed expectations. Previous experience has demonstrated that an organization of this character invariably opens up new channels which make it easier for the Bureau to extend its usefulness and cooperation with the industry which the society represents. The new organization has already proven of material benefit in this connection and constitutes a section of the American Chemical Society. The interest manifested, results accomplished, and the growth of the organization have justified its petitioning that it be made a self-governing division. At the last meeting 33 technological papers, including 4 foreign contributions, and covering every phase of the sugar industry, were presented.

COLORIMETRY.

General Nature and Scope of the Bureau's Work in Color Standardization and Colorimetry.

"Color" is one of the items of interest in describing and specifying various materials and objects. It is a fact that the commercial value of many materials depends in part upon their color. It is, of course, obvious, on first thought, that the color of a dye or a pigment or a railway signal glass is its dominating characteristic, the property which first comes to mind when it is thought of. While less obvious to those unacquainted with the trade in particular commodities, it is also a fact shown by the Bureau's correspondence that the most varied industries are intensely interested in and concerned with the standardization and control of the color of their products. Among the objects and materials for which various interests have asked the Bureau to provide color standards or better methods of color measurement and specification may be mentioned the following: Railway signal glasses, dyes, paints and pigments, paper, lime, gypsum, flour, tobacco, oils, butter and oleomargarine, ceramic wares, and others. In fact, it appears from inquiries and requests received that some one is likely to be interested in specifying the color of almost any material or object that can be named. Much of this interest is wholly commercial because the price is dependent upon color, and the buyer and seller must accordingly have accurate and

reliable means of specifying this property. Aside from this there is the purely scientific interest. The botanist requires means of describing the colors of his materials, likewise the chemist, geologist, the ornithologist, and other investigators in various fields. The anthropologist desires to specify the color of the skin of various races and hybrids. The psychologist and physiologist desire to specify the colors of cards and papers which they use in their experiments on vision. The list might be augmented, but these illustrations will suffice for examples. Thus the Bureau's work in colorimetry had its origin in an insistent demand from many sources for color standardization.

The meeting of these demands in a satisfactory way requires first of all a vast amount of fundamental research. Unlike older sciences and arts, the methods and standards of colorimetry are not well established. There are, in general, no ready-made standards, instruments, and methods to be recommended. The work, therefore, consists largely in the development and testing of suitable methods, instruments, and standards. The problems met are of unusual difficulty, involving questions in physics, psychology, and physiology at the same time. Although we may speak of the "color of an object," color is strictly a sensation determined by the nature of the light entering the eye. Fundamentally, then, the specification of color from an obective point of view takes the form of a specification of the light emitted by a light source, the transmission of a transparent material, or the reflection of an opaque material. A large part of the work is accordingly the measurement of such characteristics by spectrophotometry or other means. In addition, attention must be given to the study of color vision.

Although the importance of prosecuting research in this field must be particularly stressed, it should also be noted that many practical routine tests are currently made, in so far as knowledge and methods are available. Thus, railway-signal glasses are tested by a perfectly well-established method of determining their transmission for lights of various hues. Glasses designed to protect the eyes from injurious radiant energy and "ray filters" for photographic work are tested in the same way. The spectral distribution of light sources is likewise a matter of well-established test. The spectral reflection of paints, dyes, fabrics, and other materials are determined on request.

Because of the undeveloped nature of the subject, as well as its limited facilities, the Bureau is able to satisfactorily meet only a small part of the demands made upon it in this field of standardization. But the subject is being systematically developed, and practical requirements are being met as rapidly as these limitations will permit. For other information on progress, reference is made to previous reports, 1913 to 1920, inclusive.

The Standardization of "White Light."

It is obvious that the cardinal problem of color standardization is to fix a standard for "white." This is the keystone of the whole structure. We approach the problem from the viewpoint of common knowledge and common sense. Sunlight is commonly called "white light," but the light of a candle or oil flame is almost as generally

also called white. If the two be immediately compared, the former will appear intensely blue, the latter intensely yellow. Among common electric glow lamps we may arrange them in order as to color between the candle and the sun. Thus, carbon filament, vacuum tungsten, gas-filled tungsten. The light of the carbon arc is blue as compared to the gas-filled tungsten glow lamp, but yellow as compared with the sun. The sun appears yellow in comparison with some of the stars and blue in comparison with others. Moreover, the color of sunlight varies over wide limits during one day and during the year. What, then, shall we take as a standard "white light"? One method would be to arbitrarily say without further discussion that the average noon sun (or some other source) is white; that is, settle the question by definition. It is perhaps more reasonable to define white light as the light (of an ideal complete radiator) which will evoke the hueless sensation commonly called white or gray by the average observer under certain standard conditions, contrast and fatigue effects being eliminated, and then find this light by experiment. Even if we do not set up such a definition prior to the experimental determination, it must be admitted that the results of such an experimental determination would be of the utmost interest in considering the formulation of the definition. A preliminary determination of this kind was completed during the year. The results were communicated to the American Physical Society and the Optical Society of America in December, 1920. (Jour. Op. Soc. of Am., Mar., 1921, p. 205.) The complete account of this work is now in press as a Bureau of Standards Scientific Paper. Since only four observers were included in this preliminary determination, no final standard can be definitely recommended as yet. The results of these four observers, however, indicate that white light is fairly well represented: (1) Theoretically, by the light from a complete radiator (or nonselective incandescent solid) at a temperature of about 5,200° absolute centigrade; (2) practically by the light of the average noon sun at Washington. The development and practical testing of an experimental method suitable to attack the problem is regarded as a more important result than the mere finding of these preliminary values. It is now desirable that similar determinations be made by a large number of observers over a period of time, and that the conditions of the experiment be varied in several ways.

The Color of Various Illuminants.

The standard white light being established, it is next important to grade other illuminants as to color. Work on this problem is in progress, in cooperation with other scientific and technical laboratories. An apparatus for providing standard light such as would be emitted by a complete radiator at very high temperatures has been devised and described. (Jour. Op. Soc. of Am., March, 1921, p. 178.) This apparatus is now in practical use in the measurement of the "color temperature" of high efficiency gas-filled lamps, the electric arc, and working standards of "artificial sunlight."

Spectrophotometric data on several high intensity arcs used in military searchlamps have been published. (Bur. Stds. Tech. Paper No. 168, August, 1920.)

The Relation Between Color and the Spectral Distribution of Light.

In general, the same color (sensation) may be evoked by light of many different spectral distributions (stimulus). Thus arises one of the major difficulties of color standardization. It is a matter of importance to find what conditions are satisfied by stimuli evoking the same color. A great deal of data accumulated incident to other work has now indicated one of these conditions. The subject is too intricate to be profitably dealt with in detail in this report, and reference is therefore made to the published paper describing the relation found. (Jour. Op. Soc. of Am., September, 1920, p. 389.)

A Direct Reading Spectrophotometer for Liquids.

As emphasized in previous reports, the ultimate physical basis of colorimetry is spectrophotometry. A notable handicap to progress has been the lack of spectrophotometers suitable for rapid as well as accurate work. Such an instrument is needed particularly now in the vegetable-oil and dyestuff industries. A new instrument has therefore been designed at the Bureau and constructed in its instrument shop. This instrument has been exhibited to the American Oil Chemists Society and the American Physical Society. It has also been described to the Washington section of the American Chemical Society, and will probably be exhibited at the Chemical Exposition next September. It has already met with considerable interest among chemists and oil technologists. (See, e. g., Cotton Oil Press, January, 1921, p. 42, and Chem. and Met. Eng., May 25, 1921, p. 942.) A leading instrument maker is undertaking its commercial manufacture, and the Bureau is cooperating with this firm in further development of this and related apparatus for spectrophotometric work. The Bureau of Standards Scientific Paper describing this instrument is in course of preparation.

A New Study of the Leucoscope.

The "leucoscope" is an optical instrument invented by Helmholtz and his pupils about 1878, but has been practically unknown and forgotten in recent years. The instrument is of interest in the study of color vision, and it now appears to have some practical value as an optical pyrometer. At the time of the early work with it the results obtained could not be correlated and presented to the best advantage because of the lack of other data and clear concepts which have subsequently become available. During the past year a new study of the instrument has been completed in the light of modern knowledge and ideas, and a report upon this study has been published. (Jour. Op. Soc. of Am., November, 1920, p. 448.)

The Spectral Transmissive Constants of Dyes.

The optical transmissive or absorptive properties of dyes in solution are of primary importance in practical analysis, identification, and standardization of dyes, as well as in a theoretical study of chemical constitution.

An extensive investigation, the plan of which was given in last year's report, has been suspended during the past year because of lack of personnel to carry it on. The results already obtained have been compiled and are now ready for publication.

The Spectral Transmissive Constants of Vegetable Coloring Matters.

Some work is being done in cooperation with the Bureau of Plant Industry, Department of Agriculture, on the transmissive constants of the pure vegetable coloring matters—xanthophyll, chlorophyll, and carotin. These data will be of interest in the color grading of vegetable oils and the chemical estimation of these coloring matters.

The Color and Spectral Transmissivity of Vegetable Oils.

A large amount of data on the color and spectral transmissivity of vegetable oils (cotton seed, peanut, soya bean, sesame) has been accumulated as a result of the Bureau's long-continued investigation of this subject. Fragments of this have heretofore been published. These data are now being prepared for publication in extenso. They will be of interest to the oil-refining industry.

The Spectral Reflection of Various Materials.

A usual preliminary to the study of the color grading of any particular kind of material is the determination of the spectral reflection of a large number of representative samples. Such preliminary studies of various papers and of lime, gypsum, and enamels have been made in cooperation with the technologic sections of the Bureau dealing with these materials. In the case of lime and gypsum this has led to the publication of tentative recommendations as to color specifications. (Chem. and Met. Eng., June 15, 1921, p. 1054.)

Investigation of the Lovibond Color Scale as Used in the Color Grading of Vegetable Oils.

A thoroughgoing spectrophotometric and colorimetric examination of a large set of Lovibond glasses such as are used in the color grading of vegetable oils has been completed and the results are being prepared for publication as a Bureau of Standards Technologic Paper.

An Examination of the Munsell Color System.

This is a large system of colored charts intended, primarily, for instruction of art students and used practically as standards in the color-printing trade. At the request of its publishers the Bureau has determined the spectral reflection of a number of these standards. The results have been published during this year. (Bur. Stds. Tech. Paper No. 167.) In this paper the scale of "value" (artist's term for luminosity, brightness, or brilliance) is also discussed and certain suggestions as to the further improvement of the system are made.

REFRACTOMETRY AND OPTICAL INSTRUMENTS.

In addition to the routine tests of optical materials and the performance of optical instruments, this section has devoted its time primarily to completing the range-finder investigation reported last year; to a comparative laboratory study of the various precision methods for testing the performance of photographic lenses, with the object of adopting the most preferable; to developing a series of

laboratory telescopes of standardized design; to designing a refractometer of high precision, a tool polarimeter for precision analysis of elliptically polarized light, a simple and relatively inexpensive range finder for general survey work; to an investigation of the effect of the presence of strain on the performance of large reflecting prisms; and to an investigation of a method for illuminating cross lines in telescopes. The completed activities are summarized below.

Range-Finder Investigation.

This investigation, which was carried out in cooperation with the Ordnance Department of the United States Army and described in detail in last year's report, was completed during the current year. It consisted of a laboratory and field test of a number of different types of 80-centimeter base range finders, the field test being carried out at Fort Sill, where about 21,000 observations by different men in the service were made. From these observations both the probable accuracy of the different types of instruments and the probable error of the observers were deduced.

Standardized Laboratory Telescopes.

Very acceptable improvements are possible in general laboratory telescopes from the standpoint of choice of optical parts in which the number should be reduced to a minimum, interchangeability of oculars and micrometers, and range in the depth of focus. The design of three different sizes of such standardized laboratory telescopes has been carried out for the Bureau laboratories, and the smallest of the three has been constructed in the Bureau's instrument shop and tested. It has a relatively large range of focus, from 17 centimeters to infinity, and "exit pupil" well back from the ocular, so that the eye can be placed at a convenient distance from it and yet command the whole field of view; good definition and color correction; and a neat mechanical design.

Design of a High-Precision Refractometer.

A refractometer for measuring indices of refraction to the sixth significant figure instead of the customary fourth or fifth has been designed and is now being constructed by an instrument maker. This refractometer has the same accuracy as a spectrometer and is superior to that instrument in that it requires the measurement of only one angle instead of two. It excels it in that, having a provision for reversing the circular scale, eccentricity errors are largely eliminated. Compared with other designs of refractometers, this one is self-checking while the others are not, and being horizontal, does away with one refraction of the light, which thus permits it to be used with faint spectral lines, e. g., the G–line, where others fail.

Design of a Universal Polarimeter.

As commonly used, the name polarimeter is generally applied to an instrument for measuring with precision in circular degrees the rotation of the direction of vibration of plane polarized light by various media through which it may be passed. Polarized light, however, has other properties which must be measured if that light

is to be precisely specified. In general, the light vibration is elliptical in form, varying between the rectilinear path (or plane polarized light) on the one hand, and a circular path (or circularly polarized light), on the other. A universal polarimeter is an instrument, therefore, which will measure any elliptical vibration, the direction of motion producing it, and the direction of the major axis of the ellipse. A Tool universal polarimeter has been designed by the optical instruments section in cooperation with the polarimetry section and built in the Bureau's instrument shop. This polarimeter is the combined application of the half-shade Nicol prism and the half-shade Brace elliptic analyzer to the Stokes method of elliptic analysis by a variable-azimuth compensator. It will measure ellipses whose width is 0.2 their length (that is, "ellipticity"=0.2) to an accuracy of 1 per cent, and for circularly polarized light, where the Stokes analyzer fails completely, it will measure this ratio to 0.05 per cent. For small ellipses it will measure azimuths (direction of major axis) to 0.02 circular degrees, while for the larger ellipticities the accuracy of measurement is correspondingly high. The instrument is, furthermore, designed so that it can be readily converted into either a Brace elliptic analyzer, which is specially applicable to the measurement of very small ellipticities, a Stokes analyzer, or a simple rotation polarimeter.

Intensifying Lens for a Large Aperture Astronomical Reflector.

For the same quantity of light received on the photographic plate from each point of the object the necessary exposure time increases proportionately to the area of the plate which a given scene covers; that is, the speed varies inversely as the square of the magnification. At the request of Dr. Harlow Shapley, of Mount Wilson Observatory, an intensifying doublet was designed in the optical instruments section and constructed by the Bureau's expert optician for increasing the speed of their large reflector by theoretically four times. This lens was first computed with great care and the curves repeatedly checked during the process of grinding. The laboratory test of the finished lens was very satisfying, so that the final working test is awaited with confidence.

Design of Cameras for the Navy.

Improvements in the design of a spotting camera and a long-range motion-picture camera for the Bureau of Ordnance of the Navy were made in the optical instruments section and the mechanical modifications carried out in the Bureau's instrument shop. These improvements related principally to increasing the speed of the cameras and reducing the mechanical vibrations of the operating mechanism.

Special Test of Lenses for the Air Service.

Very careful and complete tests of a number of long-focus high-speed camera lenses were made for the Air Service of the War Department, with the object of selecting the kind most suitable for use. For making these tests it was necessary to design and construct larger attachments for the testing apparatus. With this extra equipment the Bureau is now fitted out for the expeditious testing of camera lenses of all sizes.

RADIOMETRY.

Investigations in the general subject of thermal radiation have been confined principally to the spectral transmission of materials, to the improvement of instruments for measuring thermal radiation, and to the effect of thermal radiation upon the electrical conductivity of matter.

Infra-Red Transmission Spectra.

Spectral transmission measurements were made on a series of animal, vegetable, and mineral oils for the purpose of determining whether by this means it is possible to detect the adulteration of one oil by another. For example, cottonseed oil in olive oil. It was found that the transmission spectra of all these oils are so closely the same that they are difficult and uncertain of identification. This was, of course, to be expected in view of the principle established almost two decades ago, that the great groups of chemical compounds, for example, the fatty acids, have similar absorption spectra.

Spectral Transmission Screens.

The ordinary spectroradiometer is not applicable for determining the spectral energy distribution of sources which are weak in thermal radiation; for example, of stars, and of luminescence of terrestrial objects. It is therefore necessary to resort to various expedients, one of which is the isolation of wide spectral regions by means of screens. Such screens are useful also for producing light stimuli of large area for botanical, photoelectrical, and photochemical investigations.

During the past year a further search was made for screens having a uniformly high transmission in one part of the spectrum, terminating abruptly into complete opacity in another part of the spectrum. It was found that by suitable combinations of colored and clear glass, also quartz (all of proper thickness) and 1 centimeter cell of water, it is possible to determine the radiation intensity in the spectral region for the intervals between 0.3μ, 0.4μ, 0.5μ, 0.6μ, 0.7μ, 1.4μ, 2.8μ, 4.1μ, and 9μ (μ equaling 0.001 mm.) without involving any important correction for energy losses other than that of surface reflection. This offers a convenient and fairly reliable means of determining the spectral energy distribution of stars, also a means of determining the spectral type of the companion stars of spectroscopic binaries. For example, preliminary measurements made with the water cell are to be interpreted as showing that the companion star of the spectroscopic binary, β *Orionis*, is red and of too low luminosity to affect the photographic plate.

A Portable Vacuum Thermopile.

Vacuum radiometer containers which are provided with windows of fluorite or rock salt usually leak. The evacuation changes also as the result of the slow disengagement of adsorbed gases from the radiometer receiver. As a result of these difficulties attempts to seal off the vacuum radiometer permanently from the evacuating device have not been successful.

During the past year a paper was prepared giving a description of a portable vacuum thermopile mounting of glass, in which the

evacuator, consisting of metallic calcium in a quartz test tube, is permanently attached to the container. General directions are given for operating the device, as well as data on the thermopile, which is of bismuth-silver. Observations extending over a period of about seven years are given on the behavior of vacuum thermopiles in which the vacuum is maintained by means of calcium, which has the property of combining with gases when it is heated.

Methods for Testing Glasses Used for Protecting the Eye from Thermal Radiation.

Some time was spent in working out a quick and inexpensive method for determining the opacity of eye-protective glasses to ultra-violet rays. The photographic method now used requires several hours for making such a test. By the new method, which is radiometric, the test can be made in a few minutes. This method is based upon the fact that all glasses are opaque to radiations of wave lengths less than 0.3 μ. It is therefore necessary to examine eye-protective glasses for opacity to ultra-violet radiations only of wave lengths 0.3 μ to 0.4 μ. Radiations of these wave lengths are easily obtained without employing a spectroscope by simply filtering the light from a quartz mercury vapor lamp through a suitable glass screen (Corning, G., 586J; thickness, about 2.5 mm.) placed over a vacuum thermopile or a photoelectrical cell. Measurements of 1 part in 10,000 are easily obtainable, whereas in order to make the tests comparable with the specifications of the present safety Code for Eye Protection, an accuracy of 1 part in 1,000 only is necessary.

If agreement can be obtained on this method of testing glasses for opacity to ultra-violet radiation, this Bureau could issue to manufacturers standardized transmission screens and standardized samples for check measurements to the advantage of all parties concerned.

Exclusion of Ultra-Violet Solar Radiation from Buildings.

Mention was made of this problem in the report of 1919. During the past year, in collaboration with the Chemical Division, varnishes were prepared and the ultra-violet absorptivity determined. The material is to be used on the windows of balloon hangars to prevent the ultra-violet rays of sunlight from injuring the balloon fabric.

It was found that one or two coats of a good spar varnish containing 5 to 10 per cent asphaltum varnish, applied to ordinary window glass, is an effective means of eliminating the ultra-violet from sunlight. A single coat of spar varnish containing 5 per cent asphaltum varnish, dried in a horizontal position, transmits less than 10 per cent of the ultra-violet solar radiation of all wave lengths less than 405 millimicrons.

Photoelectrical Investigations.

During the past year further investigations were made on the spectrophotoelectrical sensitivity of substances. One line of attack was the subjection of the photoelectric substance (molybdenite, stibnite) to electrical treatment; also to heat treatment for several hours at various temperatures up to 600° C.

In the temperature range up to 500° C. slow heat treatment has no definite effect upon the intrinsic photoelectrical sensitivity. At

temperatures above 600° C. the sensitivity appears to be permanently decreased or entirely destroyed.

The general experience is that stibnite becomes photoelectrically insensitive on melting and recrystallization. It is therefore of interest to record that a sample of stibnite which had been melted and recrystallized (the surface being covered with patches of acicular crystals) was found to be photosensitive, the spectrophotoelectrical reaction being the same as that of the original crystal. The photoelectrical sensitivity of stibnite and of molybdenite was not affected by passing alternating current through the material either for long or short periods.

An examination was made of the spectrophotoelectrical sensitivity of the mineral proustite, which is a double sulphite of silver and arsenic. The reaction of this mineral was found to be entirely different from that of silver sulphide. At room temperatures the photoelectrical reaction of proustite is confined practically to the ultra violet. At low temperatures the intrinsic sensitivity is greatly increased throughout the spectrum, and the maximum of the photoelectrical reaction is localized in a band at 0.578 μ.

In last year's report attention was called to the discovery of a sample of molybdenite which had a photonegative reaction, depending upon the wave length of the exciting light as well as upon the magnitude and direction of the current through the crystal. Since then further observations were made in another sample of molybdenite which exhibits this photonegative property. This particular sample is unique in that at room temperatures the photoelectrical response is proportional to the intensity of the light stimulus. Moreover, the spectrophotoelectrical reaction in quite uniform throughout the visible spectrum to 0.75μ, followed by a rapid decrease in sensitivity to zero beyond 1μ. At −80 to −100° C. the photonegative reaction appears and it is similar to that previously observed. All the new data are in agreement with the general characteristics of spectrophotoelectrical sensitivity in solids, formulated in last year's report.

DISPERSOIDS.

Intermediate betwen the general properties of matter, usually considered the field of physics, and the specific properties chiefly studied by chemists are the properties of substances dispersed in the form of fine particles (dispersoids) and as minute cellular structures (colloids). There has recently arisen an appreciation of the great industrial importance of such substances, comprising as they do practically everything met with in every-day life, from living tissue to potter's clay or "movie" films. Chemical reactions are usually considered as depending only upon the relative masses of the reacting substances and not upon their surfaces; but when such systems have not reached thermodynamic equilibrium (and this is of common occurrence in industrial processes) transformations are taking place at the surfaces between the substances. Now, the fine particles of dispersoids and the thin films forming the minute cells of colloids present enormous surfaces, so that the properties of surfaces may here be of more importance than those of masses. Indeed, it is found that dispersoids of widely different composition present com-

mon characteristics, due to the similarity of all surface phenomena. The systematic study of the properties of matter forming natural surfaces is of fundamental industrial importance.

Stratified Soap Films and Molecular Reality.

The structure of stratified soap films has been studied in collaboration with Prof. Jean Perrin, of Paris. The black spot is just two molecules thick, and the stratified layers increase in thickness in steps of two molecules. This work is new and very striking evidence of the existence of molecules and may become of practical importance in connection with the problem of lubrication at low speeds and high pressures.

Ultramicroscopic Study of Varnishes.

In connection with an extended investigation of the properties of varnish, undertaken by H. A. Gardner and P. C. Holdt, of the Institute of Industrial Research, for the Paint and Varnish Manufacturers' Association (in which several other sections of the Bureau have cooperated) ultramiscroscopic and turbidimetric studies of a series of varnishes have been made. This work is reported in Circular 127 of that institute.

Work on a Turbidity Standard.

The question of a turbidity standard for water analysis is being further studied. Curves have been obtained for the rate of settling of particles of different sizes, giving the size distribution of suspended particles. A report of this work was given before the American Water Works Association in Cleveland, June 9, and will be published in their journal.

INTERFEROMETRY.

The principle of interference of light waves has been applied in calibrating standards of length and in measuring the changes in such standards with time, temperature, and heat treatment. It has also been used in determining the changes in the physical properties, such as expansivity, refractive index, and density of substances. Very precise results are obtained due to the extreme sensitivity of the methods.

Thermal Expansion.

Using interference methods, the thermal expansion of small samples, 1 to 10 millimeters in length, can be accurately determined. During the past year measurements have been made on a large number of samples of glass, tempered steel, cast steel, monel metal, porcelain, "sealing-in" wires, etc. A description of the method and apparatus and the measurements made on several different kinds of glass was published in Bureau of Standards Scientific Paper No. 393 and in the Journal of the Optical Society of America, May, 1920.

Calibration of Length Standards.

Precision gauges which are used as length standards in machine shops are calibrated by comparison with the Bureau's end standards. These end standards have been calibrated by comparison with the

standard light waves. A description of the methods and apparatus used in determining the length of end standards and for making the comparisons between end standard and precision gauges was published in the American Machinist, September 30, 1920, and as a Bureau of Standards Scientific Paper.

Ruling of Line Standards, Using Light Waves as Fundamental Length Standards.

Apparatus has been constructed for ruling line standards, using light waves as the fundamental length standard. Scales correct to one one-hundred-thousandth of an inch have been ruled. With better-controlled mechanical conditions, more accurate results can be obtained.

Index of Refraction of Glass.

Measurements of the variation of the refractive index and dispersion with temperature have been made on several different types of optical glass. The glasses were tested up to their softening temperature, which varied from 500 to 600° C. All showed an increase in refractive index with rising temperature or decreasing density. A paper describing the results of this investigation will appear shortly.

Testing of Plane Surfaces.

The planeness of optical surfaces is most accurately tested by means of the interference fringe seen in monochromatic light. The methods and apparatus used in making such test are described in an article published in the Journal of the Optical Society of America, November, 1920.

PHOTOGRAPHIC TECHNOLOGY.

Aside from the important problem of increasing the speed and resolving power and also improving the contrast results to be obtained from photographic plates and printing out papers, the next in importance is probably that of developing methods for testing these characteristics so that different operators will arrive at the same conclusion as to the relative value of given photographic materials. Accurate measurements of the light sensitive qualities of photographic materials are very difficult to make and may be very unreliable, first, because of the lack of complete knowledge of the complex laws to which the materials are subject and the complicated apparatus required, and second, because of the variation in the measurements obtained from materials which have been apparently subjected to identical treatment and which is found not only in materials of the same brand taken from different packages, but in materials taken from the same package, and even in different parts of the same piece. Such a condition is not so surprising when the extraordinary sensitiveness of modern photographic material is taken into account. These various reasons account for the slow development of standardized methods of testing photographic materials. The Bureau believes that the time has come when standardized methods can best be introduced and is therefore giving, in its photographic laboratory, special attention to sensitometry investigations.

Sensitometry.

The new sensitometer noted in the last annual report is completely described in United States Patent No. 1382272, obtainable from the Patent Office at 10 cents per copy. This patent having been dedicated to the public the apparatus may be constructed and used by anyone without payment of royalty.

The filter factor apparatus mentioned in the last annual report has been described in Bureau of Standards Scientific Paper No. 409, under the title "A New Method for Measuring Photographic Filter Factors."

Color Sensitizing of Photographic Plates by Bathing.

This work has been carried on in cooperation with the spectroscopy section and is described in the report of that section's activities.

SEARCHLIGHT INVESTIGATION.

This section, which was organized to carry out, in cooperation with the Corps of Engineers of the War Department, certain investigations in connection with searchlight illumination and to perform necessary tests on search lamps and search-lamp accessories, was discontinued in February when the Engineer Corps transferred their activities to the Engineering Testing Laboratory at Schenectady.

Completion of a Focus-Testing Apparatus for Searchlight Mirrors.

As described in the last annual report, an apparatus of special design was being constructed to explore the form of the reflecting surface of searchlight mirrors. This was completed and successfully used for testing a number of mirrors. The method not only reveals the variation of the mirror from a perfect form, but at the same time shows directly whether or not this variation is within the tolerance imposed by the size of the arc.

Design of a Simple Reflectometer for Testing the Reflecting Power of Mirrors.

A simple portable reflectometer for use by inspectors and others in the factory and elsewhere was designed. Repeated calls were made during the war by engineers for such an instrument. A description is given in the January number of the Optical Journal of America, under the title "The Use of the Ulbricht Sphere in Measuring Reflection and Transmission Factors."

Effect of Diffusion of Light from a Searchlight Beam.

For the purpose of determining the effect of the diffusion of light from a searchlight beam on the visibility of a target, the brightness of such beams and the amount of polarized light in them, when using a gold reflector as well as the ordinary reflector, was measured at various directions and distances from the beam. The results of this investigation are embodied in a forthcoming publication. Among the most important conclusions derived is that a gold mirror, which by virtue of its giving less diffusible light reduces the brightness of the background against which the target must be

viewed, reduces at the same time, however, the brightness of the target, so that the latter is less visible with the gold than with the silver mirror in the search lamp.

TESTING, INFORMATION, AND PUBLICATIONS.

Testing.

A total of about 2,200 tests were made, covering the following: Quantitative spectroscopic tests for minute traces of impurities in supposedly chemically pure metals; precision tests of polarimeters and quartz control plates for the same; tests of exchange samples of raw sugar for the quantity of sucrose and water present, sugar content, and density of molasses; performance of photographic lenses, binoculars, telescope lenses; precision tests of refractometers, refractive indices, and light transmission of optical materials; spectral transmission of various glasses and ray filters, spectral reflection of paper pulp, standard colored cards, "white" enamel, dyes in powder form and in fabrics; tests of quartz mercury vapor lamps and eye protective glasses for both radiation and mechanical strength; ultramicroscope tests of dispersive materials; planeness of optical surfaces, end gauges used for secondary standards of length, and thermal expansion of bodies having small dimensions.

Information, Activities in Societies, Etc.

A considerable part of the time of the staff is consumed in imparting information, covering the entire field of optics, to visitors and by correspondence with individual investigators, members of other Government bureaus, and representatives of industrial concerns. The most numerous inquiries are in regard to methods of making various optical measurements, hypersensitizing photographic plates, cementing of prisms and lenses, testing strain in optical glass, silvering of glass, and color grading; also, concerning the various light filters, lamps for dye fading, and photosensitive substances for invisible signaling.

During the year the Bureau has cooperated with other organizations, as follows: The Optical Society of America in the standardization of the nomenclature and in the compiling of standard data needed in spectroscopy, colorimetry, radiometry, and photography. A representative of the Bureau has served on each of the society's committees. The American Institute of Graphic Arts in the standardization of process color printing. The Bureau's part in this has consisted in determining the spectral transmission of filters and the spectral transmission of inks submitted by the Institute. A representative of the Bureau has served on their committee. The American Oil Chemists Society on the Color Grading of Vegetable Oils. The society's committee on this subject held one meeting at the Bureau. (See Cotton Oil Press, September, 1920, p. 49, and January, 1921, p. 42.) At the request of this committee an intercomparison of 16 glasses used as color standards for grading oil in different laboratories was made at the Bureau and the results published. (Cotton Oil Press, January, 1921, p. 43.) The Calco Chemical Co. on the spectral reflection of dyed fabrics. The Bureau of Mines, studying questions relating to the optical properties of smoke and dusts. The American Chemical Society, to investigate the tech-

nical uses and limitations of the refractometer as applied to the sugar and glucose industries.

Publications.

The following publications have been issued during the year by members of the Optics Division staff:

Measurement of wave lengths (W. F. Meggers). Dictionary of Applied Physics, Sir Richard Glazebrook, editor.

Wave-length measurements in arc spectra photographed in the yellow, red, and infrared (F. M. Walters), B. S. Sci. Paper No. 411.

Wave lengths longer than 5,500A in the arc spectra of yttrium, lanthanum, and cerium (C. C. Kiess), in press.

Standard wave lengths (W. F. Meggers), Jour. of Op. Soc. of Am., July, 1921.

Interference measurements in the spectra of argon, krypton, and xenon (W. F. Meggers), in press, presented before American Physical Society, Washington, D. C., April, 1921.

New lines in the spectrum of oxygen (C. C. Kiess), publications of the American Astronomical Society, vol. 4, p. 170, September, 1920; presented before American Astronomical Society in September, 1920, at Northampton.

The excitation of the enhanced spectrum of magnesium in a low-voltage arc (Paul D. Foote, W. F. Meggers, and F. L. Mohler), Phys. Rev., in press.

Resonance potentials and low-voltage arcs for metals of the second group of the periodic table (F. L. Mohler, Paul D Foote, and W. F. Meggers), B. S. Sci. Paper No. 403

The application of the Clerget method to dilute sucrose solutions (Richard F Jackson and Clara L. Gillis), Louisiana Planter, vol. 66, p. 141, Feb. 26, 1921; Facts about sugar, Vol. XII, p. 190, Mar. 5, 1921; and International Sugar Journal, vol. 23, p. 217, April, 1921.

The complex applicability of the modified Clerget method (Richard F. Jackson and Clara L. Gillis), Louisiana Planter, vol. 66, p. 380, June 11, 1921; Facts about sugar, Vol. XIII, p. 10, July 2, 1921; and International Sugar Journal (date of this journal in which article appears as yet unknown).

Preparation of galactose (Earl P. Clark), Jour. of Biol. Chem., vol. 47, p. 1, June, 1921.

Absorption of heat in glass (A. Q. Tool and C. G. Eichlin), Jour. Op. Soc. of Am., Vol. IV, p. 340, September, 1920.

An Examination of the Munsell color system (Irwin G. Priest, K. S. Gibson, and H. J. McNicholas), B. S. Tech. Paper No. 167; presented at meeting of Optical Society of America, New York, February, 1920.

Color and spectral composition of certain high-intensity searchlight arcs (Irwin G. Priest, W. F. Meggers, K. S. Gibson, E. P. T. Tyndall, and F. J. McNicholas). B. S. Tech. Paper No 168.

Note on the relation between the frequencies of complementary hues (Irwin G. Priest), Jour. Op. Soc. of Am., Vol. IV, No. 5, September, 1920.

Report on calibration of sixteen lovibond red glasses (Irwin G. Priest). Cotton Oil Press, January, 1921.

A new study of the leucoscope and its applications to pyrometry (Irwin G. Priest), Jour. Op. Soc. of Am., vol. 4, November, 1920; presented before meeting of the Optical Society of America, December, 1920.

The spectral distribution of energy required to evoke the gray sensation (Irwin G. Priest), Jour. Op. Soc. of Am., vol. 5, No. 2, p. 205, March, 1921; presented before a meeting of the Washington Philosophical Society, May, 1921; Optical Society of America, Chicago, December, 1920; in press.

A method of obtaining radiant energy having the visible spectral distribution of a complete radiator at very high temperatures (Irwin G. Priest), Jour. Op. Soc. of Am., vol. 5, No. 2, p. 178, March, 1921.

Infra-red absorption spectra of vegetable oils (K. S. Gibson), Cotton Oil Press, September, 1920.

Relative spectral transmission of the atmosphere (Enoch Karrer and E. P. T. Tyndall), B. S. Sci. Paper No. 389.

Preliminary note on the relations between the quality of color and the spectral distribution of light in the stimulus (Irwin G. Priest), Jour. Op. Soc. of Am., Vol. IV, No. 5, p. 388, September, 1920.

The spectral transmissive properties of dyes; I, of the permitted food dyes in the visible, ultra-violet, and near infra-red (K. S. Gibson, H. J. McNicholas, W. E. Mathewson, E. P. T. Tyndall, and M. Katherine Frehafer), in press.

Abstract of report on investigations of the color and spectral transmissivity of vegetable oils (Irwin G. Priest), Cotton Oil Press, p. 95, July, 1920; presented before meeting of the American Oil Chemists Society, New Orleans, May, 1920.

The cemented telescope objective of Barium crown and flint (I. C. Gardner), Jour. Op. Soc. of Am., Vol. IV, No. 5, p. 274, September, 1920.

Positive and negative photoelectrical propertiese of molybdenite and several other substances (W. W. Coblentz), B. S. Sci. Paper No. 398.

Infra-red transmission and refraction data on standard lens and prism material (W. W. Coblentz), B. S. Sci. Paper No. 41.

Present status of the constants and verification of the laws of thermal radiation of a uniformly heated enclosure (W. W. Coblentz), B. S. Sci. Paper No. 406; Jour. Op. Soc. of Am., 5, p. 131, 1021; Ibid., including a complete discussion of instruments, methods, formulæ, etc., Glazebrook's Dictionary of Physics.

Spectrophotoelectrical sensitivity of proustite (W. W. Coblentz), B. S. Sci. Paper No. 412.

Some general characteristics of spectrophotoelectrical conduction in solids (W. W. Coblentz), Jour. Op. Soc. of Am., 4, p. 249, 1920.

Physical research methods (Book published by the National Research Council; light, chapters on; I, Light sources, filters, etc.; III, Spectrometers; and VI, Spectroradiometry, by W. W. Coblentz.)

Transmission and refraction data on standard lens and prism material with special reference to infra-red spectroradiometry (W. W. Coblentz), Rep. to the Op. Soc. of Am. committee on spectroradiometry, Jour. Op. Soc. of Am., 4, p. 32; 1920.

Instruments and methods of radiometry (W. W. Coblentz), report to Op. Soc. of Am. committee on spectroradiometry, Jour. Op. Soc. of Am. 5, p. 259; 1921.

A portable vacuum thermopile (W. W. Coblentz), in press.

Spectroradiometric investigation of the transmission of various substances, II (W. W. Coblentz), in press.

Sur l'Espaisseur des lames strafifiées (P. V. Wells) Gauthier-Villars, Paris, 1920; presented before the British Association at Cardiff, Wales, August, 1920.

On the dilution method of counting bacteria (P. V. Wells), Jour. Wash. Acad., June, 1921.

On the theory of the geometric mean (P. V. Wells), in press.

Turbidimetry of water (P. V. Wells), presented before the American Water Works Association meeting at Cleveland, June 9, 1921 (Jour. Am. Water Works Ass'n, 1921).

Measurements of the thermal dilatation of glass at high temperatures (C. G. Peters and C. H. Cragoe), B. S. Sci. Paper No. 393.

The calibration and dimensional changes of precision gage blocks (C. G. Peters and H. S. Boyd). American Machinist. Sept. 30. Oct. 7, 1920.

Testing of plane surfaces by interference methods (C. G. Peters and H. S. Boyd), Jour. Op. Soc. of Am., November, 1920.

A new method of measuring photographic filter factors (R. Davis), Jour. Op. Soc. of Am., Vol. IV, No. 5, September, 1920; B. S. Sci. Paper No. 409; Jour. Roy. Photo. Soc., April, 1921.

An atlas of photographic negative emulsions (confidential report) (R. Davis and F. M. Walters, jr.). Sept. 23, 1920.

Sensitometer for testing plates and films, Patent No. 1382272, issued June 21, 1921, to R. Davis.

The use of the ulbricht sphere in measuring reflection and transmission factors (Enoch Karrer), Jour. Op. Soc. of Am., Vol. V, No. 1, p. 96, January, 1921.

The papers listed below were presented before meetings of scientific societies during the year:

Sugar section of the American Chemical Society, Chicago, September, 1920:

Comparative analyses of refined sugars (Frederick Bates and associates).

Commercial production of d-mannite (W. B. Newkirk and C. F. Snyder).

Glass vacuum pan for laboratory use (M. J. Proffitt).

The composition and preparation of a sugar sirup of maximum solubility (R. F. Jackson and C. L. Gillis).

Determination of the density of molasses (W. B. Newkirk).

Determination of sucrose and true raffinose in beet products (R. F. Jackson and C. L. Gillis).

Sugar section of the American Chemical Society, Rochester, N. Y., April, 1921:
Two single tests for the control of the crystallizer and centrifugal machine work (M. J. Proffitt).
The determination of color and decolorization in sugar products (H. H. Peters and F. P. Phelps).
Preliminary note on the causes of caking in sugar (M. J. Proffitt).
Solubility of dextrose in water (R. F. Jackson and C. L. Gillis).
Washington Philosophical Society, December, 1920:
Optical basis of Bittinger's camouflage painting (Irwin G. Priest and M. K. Frehafer).
Washington Philosophical Society, May, 1921:
Self-contained range finders and their errors (I. C. Gardner).
American Physical Society, Washington, April, 1921:
Stratified soap films and molecular reality (P. V. Wells).
American Physical Society, Chicago, December, 1920:
Expansion of sealing-in wires (C. G. Peters).
Index of refraction of glass at high temperatures (C. G. Peters).
Double refraction of glass tubing, etc., as indicating the strains present (A. Q. Tool and C. G. Eichlin).
Optical Society of America, Chicago, December, 1920:
Further results on the heat absorption of glass (A. Q. Tool and C. G. Eichlin).

By invitation the chief of the colorimetry section gave a lecture on "Spectral reflection" to the technical staff of the Calco Chemical Co. in February, and the chief of the Optics Division gave a lecture before the Franklin Institute at Philadelphia in April and before the Rochester branch of the American Optical Society at Rochester in May on "The polarimeter and its practical applications."

5. CHEMISTRY.

The work of this division includes the investigation of the chemical composition and purity of materials, studies of chemical properties and constants, researches in connection with methods of analysis, the preparation of specifications for technical materials for other departments of the Government and for industrial and scientific laboratories. The Chemistry Division has general supervision of all chemical work at the Bureau. In practically all questions of standardization or research the purity of the materials involved is an important factor. Much of the work of this nature supervised by the Chemistry Division is described under the appropriate headings elsewhere in this report.

ELECTROCHEMISTRY.

Included in this work are studies of electrodeposition used in electrotyping and electroplating, the latter being made up of investigations of zinc, lead, nickel, copper, silver plating, etc.

Electroplating Investigations.

The principal work on electrodeposition during the year has been in connection with a plant for the electrolytic reproduction of engraved printing plates at the Bureau of Engraving and Printing, reference to which was made in the last annual report. This plant has been maintained in satisfactory operation during the year, and the Bureau of Standards has cooperated in bringing about improvements and economies. The experience gained by the staff from contact with actual operating conditions will no doubt be of value in the study of other processes of electrodeposition and will insure a better understanding of the problems likely to be met in commercial plants. This work emphasizes the need for accurate and reliable information upon electrodeposition and the value of definite control work in order to insure uniformly satisfactory products. Even though the conditions met in this plant were somewhat specialized, there is no doubt that problems similar to those there encountered

exist in practically every plant devoted to electroplating or electrotyping.

One of the principal requirements of the above process was the production of a very durable printing surface. Special attention was therefore paid to the deposition of nickel which would have the desired hardness and other physical properties. As it was found that the addition of fluorides to nickel baths has a pronounced effect upon the hardness of the deposited nickel, special attention was devoted to the study of such solutions. One of the greatest difficulties was the development of a simple satisfactory method of analysis for these solutions. The problem was rendered more complicated by the presence of fluorides, but this experience illustrates the large amount of research work that may be involved to secure reliable methods of analysis and control.

In connection with the study of nickel solutions methods have been developed for measuring and controlling the acidity or hydrogen-ion concentration, which factor, it is believed, has an important bearing upon the character of the deposits produced under any given conditions. It is hoped that through the continuance of this work methods may be devised whereby the operators engaged in nickel deposition may be able to determine and control the acidity by means of simple comparative tests with appropriate indicators.

As the results obtained with the above nickel solutions were so satisfactory, efforts were made to adapt them to the regular electrotyping operations. A number of experiments have been conducted on such solutions at the plant of the Royal Electrotype Co., in Philadelphia. The results thus far obtained are not entirely satisfactory and are principally of value in indicating that it may require considerable study to define the special conditions to be met in each industry. One of the greatest needs of the electrotyping industry is the production of "electrotype shells" which will be as nearly flat as possible, so that they will not require an excessive amount of labor in the subsequent finishing operations. There is considerable field for study in this direction.

The Bureau is cooperating with the Navy Department in the study of the deposition of alloys of lead and tin which have proven especially useful for certain of their requirements. This process is being carried out successfully on a commercial scale, but there is a need for a study of the conditions which determine the composition and structure of the deposited alloy and for the development of simple analytical methods so that the composition may be readily measured and controlled. Such work will also be of value in throwing light upon the deposition of alloys in general, a field in which there is great need for investigation.

The section is frequently called upon to assist various divisions of the Bureau upon special problems involving the electrodeposition of metals. These problems are often of very considerable interest and in some cases at least may lead to new applications or developments of electrodeposition. In addition a considerable amount of electroplating is conducted upon equipment manufactured at the shops of the Bureau for the various divisions. While it is not possible to conduct such work upon a very large scale, facilities are

available for a considerable variety of work, and the experience thereby gained is valuable. The increasing need and demand for reliable knowledge upon electrodeposition is indicated by the large number of requests which are received for information or publications. Such requests emphasize the need for further research in this field and for a more general distribution of the Bureau publications relating to it.

In the above researches the Bureau has received cordial cooperation from various technical societies, especially from the American Electroplaters' Society, the International Association of Electrotypers, and the American Electrochemical Society. In the latter organization a division upon electrodeposition is about to be formed, which will no doubt promote interest in this field by bringing into closer contact the persons interested in such researches. The expense for travel involved in attending and addressing the meetings of such technical societies is fully justified, since the usefulness of research work is thereby greatly increased. The advisory services of an experienced electroplater which have been secured both by visits and by correspondence have proven very valuable.

It is evident that there is a very large field for further work upon electrodeposition, and that with such funds as are available or in prospect it will not be possible to make rapid progress at the Bureau upon many lines. Up to this time the principal subjects considered have been the deposition of copper, nickel, zinc, and lead, all of which require very much more investigation to place them upon a definite scientific basis. In addition there is a great need for the study of the deposition of silver, brass, gold, tin, iron, cobalt, and cadmium, and other metals which might be used to advantage if they were more thoroughly understood. The National Research Council has recently undertaken to bring before the manufacturers interested in electrodeposition the needs and possibilities for work in this field in order to secure from them financial support which will permit more rapid progress. If such funds are secured, they will be devoted to studies upon electrodeposition at the Bureau of Standards along such lines as may be recommended by an advisory committee consisting of representatives of the various technical societies. The numerous industrial applications of electroplating and its importance in determining the appearance and durability of many finished objects should lead manufacturers to support such a movement.

GAS CHEMISTRY.

Methods of purification, analysis, and testing of gases, including fuel and illuminating gas and special gases, such as hydrogen, oxygen, nitrogen, and argon, form the work of this section. Three major lines of work have been carried forward by the section during the year. In the order in which they originated they are: (1) The testing of balloon fabrics; (2) the application to industrial uses of the newly developed methods of gas analysis depending upon thermal conductivity; (3) the development of improved methods of producing hydrogen. Minor problems which have arisen from time to time will be mentioned after the more important lines of work have been presented.

Balloon Fabrics.

The first half of the year was largely occupied by an investigation of the effect of thread count and finish of the cloth upon the properties of rubberized balloon fabrics. This study was made a joint investigation by the textile section and the gas section, and the results obtained were embodied in a report dated January 20 and entitled "A Study of the Effect of Thread Count and Finish on Balloon Fabrics."

Since that report was issued the balloon fabric work has been largely a matter of routine testing of fabrics. A total of 577 tests were made upon 318 fabrics. The tests made in this laboratory upon two or three fabrics of exceptional properties led the Bureau to urge that an extensive investigation be made in an attempt to develop a new type of balloon fabric of superior qualities. An allotment was secured from the Bureau of Construction and Repair for this purpose. The laboratory facilities for testing fabrics were remodeled and much improved during the year. These changes were made necessary by the return of the instruments borrowed by the Bureau during the war.

Application of Thermal Conductivity Method of Gas Analysis to Industrial Uses.

The first period of development of this method, which the Bureau confidently believes is destined to become one of the most important analytical methods in industry and research, was described in the two preceding annual reports. This first period covered the development of a laboratory instrument and the laboratory demonstration of the possibility of applying it to numerous useful purposes. The work of the second period, which may be regarded as beginning approximately with the present fiscal year, has been to meet the requirements of plant conditions. The first installation made by this section, a single-point helium recorder at Petrolia, was very satisfactory during the time it was in operation. The 4-point recorder installed at Langley Field for the purpose of determining all the constituents of water gas and the two 6-point recorders installed at Petrolia were much less successful.

Aside from some trouble with the recording instruments themselves and an important defect in the construction of the "conductivity unit," which will be mentioned later, the mistake was made of installing apparatus so complicated as to require the care of an experienced operator where no competent man was available for the purpose, and the importance of the results to be secured did not justify the employment of one. Many details of construction also gave trouble when applied to an apparatus intended for continuous service. The shrinking of "Bakelite" insulating bushings, which caused leaks in the system, made much trouble until they were replaced by glass-platinum joints. The use of a spool of manganin wire of poor quality which changed resistance on standing is believed to have spoiled several months' work. Nevertheless, much has been accomplished by the small force available for this work. An apparatus capable of analyzing and recording the compositions of 16 various gas mixtures was constructed and calibrated for the helium plant at

Fort Worth, although when installed it was applied to only one. A recorder loaned by this Bureau to the Washington Navy Yard is in successful operation in connection with the electrolytic oxygen-hydrogen plant there. The success of this installation has led to a request from the Bureau of Engineering for the construction of 12 instruments of the same kind for use at other points.

The method has been applied successfully in the laboratory to the determination of sulphur dioxide, and an apparatus for this purpose is now under construction. It is to be installed, when completed, at the sulphuric-acid plant at the naval powder factory at Indianhead, Md. Two large manufacturers of sulphuric acid have undertaken to apply the method to the control of their plant operation, but have not as yet completed the construction of their apparatus.

A recorder was used with much satisfaction for three months in connection with the experimental hydrogen work at Trenton, to be described later. This instrument was used under the most trying plant conditions, the difficulty of sampling and cleaning the gas being quite unusual. The recorder was invaluable in this work and should prove of the greatest service in many industries and investigations, since it enables the operator of a plant to follow changes from moment to moment which can otherwise be ascertained only after an hour or more.

An apparatus has been designed and partially completed for determining the composition of balloon gas.

An auxiliary device is undergoing development which takes the place of voltmeter or potentiometer in certain measurements and which gives promise of being useful for many purposes other than that for which it was originally intended.

Hydrogen Investigations.

About a year ago the Bureau was asked to report upon the practicability of first one and then another process for making hydrogen for balloon purposes. The investigation of these processes led to the undertaking of a thorough investigation of the possibilities of two new processes, one of them largely a development of this Bureau. Funds were provided for the purpose by the Bureau of Engineering and the Air Service, and arrangements were made for modifying an existing experimental water-gas plant belonging to the Gas Engineering Co., of Trenton, N. J., to enable this Bureau to try out the two processes on a commercial scale.

The experiments on one of the methods have been completed. They demonstrated the possibility of making hydrogen from the thermal decomposition of oil at a cost much below that of any of the methods now employed by the Government for this purpose. The second method, a modification of the steam-iron process, is even more promising. Experiments on this process will be begun in the near future.

An experimental electrolytic generator constructed by the Air Service for the purpose of effecting economy in the electrolytic production of hydrogen was tested with negative results.

A ferrosilicon hydrogen plant constructed for the Navy was recently tested. Certain modifications of this plant will be tried out soon.

Airship Slide Rule.

At the request of the Bureau of Engineering an airship slide rule for simplifying certain calculations necessary in the design of lighter-than-air craft was developed and three sample rules constructed and submitted to the several bureaus interested. This rule is intended primarily to give rapid solutions of a few problems of frequent occurrence in airship navigation, but it can be used to advantage in solving a great variety of problems involving lifting powers, volumes, temperatures, pressures, altitudes, and the purity of the balloon gas. The favorable comments received from various sources and the fact that an order was immediately placed by the Air Service for a considerable number of these rules indicate that they have filled a real need.

Bibliography of Gas Literature.

A good start has been made toward compiling a practically complete bibliography of the scientific literature relating to the properties, manufacture, uses, and analysis of gases. This work was done preparatory to undertaking the preparation of a series of circulars which should present authoritative information on all the topics covered. A beginning has been made upon such a circular on gas density, including compressibility and thermal expansion. Unfortunately the compiler is leaving the Bureau and it will be extremely difficult to secure a competent successor even if funds were available for the work. The bibliography is of the utmost value to the section and to the Bureau, even in its present incomplete form.

Gas Analysis.

Two investigations in gas analysis were started during the year and both gave promise of important results but had to be abandoned because of the pressure of other work. One of these, a study of gas absorption, is of fundamental importance not only in connection with gas analysis but in the engineering problems arising in every industry in which gas is absorbed or purified.

REAGENTS AND APPARATUS.

In this work may be mentioned the study of methods of testing reagents and apparatus to be used in chemical apparatus, including study of chemical glassware, porcelain, platinum, and platinum substitutes.

Chemical Reagents and Apparatus.

Lack of funds has prevented prosecution of the very important work of testing chemical reagents. A systematic study of the so-called "analyzed reagents" involves standards of quality and standardization of methods of test and is therefore of direct value to science and the industries. For this reason means should be provided for prosecuting this work. If means are provided, this study will be undertaken in cooperation with the American Chemical Society and with the manufacturers of reagents. One of the sectional staff is a member of the American Chemical Society committee on "Guaranteed reagents and standard apparatus," and has attended several meetings of this committee and assisted in the preparation of specifications for certain reagents and apparatus.

These specifications and the report of this committee for the past year will be published in a forthcoming issue of the Journal of Industrial and Engineering Chemistry. The Association of Scientific Apparatus Makers of the United States is working in conjunction with the National Research Council, American Chemical Society, Bureau of Standards, and various other scientific bureaus of the National Government with a view to standardizing and thus cheapening the commoner and most used forms of apparatus.

Platinum Research.

The research upon the chemical and physical properties of the platinum metals has been continued. Considerable progress has been made in the purification of the metals of the platinum group. All of the palladium (about 550 grams) of this division has been refined to a degree of purity equivalent to that of the best material which the Bureau has received from the manufacturers. About 60 grams of osmium sponge of a high degree of purity has been prepared. All of the rhodium on hand has been subjected to purification. Some difficulty has been experienced in removing the last traces of lead from all of this material, but it is believed that this work will be completed in the near future, yielding about 400 grams of rhodium of exceptionally high purity. Some of the metal was considered to be sufficiently pure for use by the Heat Division in the preparation of a 20 per cent rhodium—80 per cent platinum alloy. The separation and purification of the iridium in the residues obtained from the Nitrate Division of the Ordnance Department, United States Army, has been continued. Rhodium and iridium are the most difficult to purify of the metals of the platinum group. Preliminary work has been started on the separation and purification of ruthenium.

In the purification of platinum notably successful results have been attained. About 1,100 grams of platinum has been prepared of a higher degree of purity than any the Bureau has ever obtained from the manufacturers in this country and abroad. This work has aroused considerable interest among the users of pure platinum, and requests have already been received for samples of this material to be used as a standard for comparison. The Bureau has also been requested to supply thermocouples made from this platinum and pure rhodium. For this purpose the highest purity is essential. Details of the work on the preparation of pure platinum will appear in a paper in a forthcoming issue of the Journal of the American Chemical Society.

Some preliminary work has been done in cooperation with other divisions of the Bureau on the preparation of the platinum metals alloys. With the installation of additional equipment now under way it is believed that some progress will be made in this field in the ensuing months.

In cooperation with the Heat Division an analysis was made of a platinum-rhodium thermocouple alloy purchased on the open market to determine the cause of its inconstancy at high temperatures. Tests were made of certain pieces of damaged laboratory ware to determine the cause of failure, but no positive conclusion was reached. Further work should be done in this field. A sample of platinum-iridium tubing used in the manufacture of hypodermic needles was

examined and found grossly contaminated with iron. Analysis of a dental alloy sold as containing a certain percentage of gold showed that no gold was present. Two samples of high-purity platinum wire were examined for a dental supply company. Tests were made of metallic strips used in hot-wire ammeters, of miscellaneous laboratory ware, and of a reputed platinum ore.

The Bureau advised with the Ordnance Department, United States Army, in regard to the recovery of platinum from the "contact mass" used in the manufacture of sulphuric acid in war-time powder plants.

There has been an increasing volume of correspondence relating to the platinum metals. In a letter dated July 15, 1920, the Secretary of War authorized the transfer from the Nitrate Division to this Bureau of 72.44 ounces of platinum residues previously loaned to this section.

The United States Assay Office, continuing its cooperation of previous years, has made for the Bureau several pieces of platinum laboratory ware.

Platinum Theft.

About 80 per cent of the platinum laboratory ware stolen from this Bureau on March 18, 1920, was recovered on March 23, 1921. Assistance was rendered the Department of Justice from time to time in its investigation and prosecution of the theft of platinum from the Old Hickory powder plant, near Nashville, Tenn. This assistance took the form of chemical analyses of some of the metal in question and expert testimony at the trial of the persons implicated.

Miscellaneous Tests.

In cooperation with the manufacturers, tests were made of American-made filter paper, representing quantity production. The results indicated that this paper is satisfactory for most purposes, but should be improved for the complete retention of very fine precipitates in exact analysis. Samples of asbestos were examined for two mining companies and found unsuitable for use in analytical work.

ANALYTICAL METHODS AND STANDARD SAMPLES.

These investigations cover general methods of chemical analysis, with special reference to methods of standardization and the preparation and analysis of standard samples of iron, steel, alloy steels, ores, brasses, bronzes, chemicals, etc.

Standard Analyzed Samples.

The number of standard samples called for during the fiscal year 1920–21 was 4,016, as against 5,676 in the year 1919–20. The distribution was as follows:

Irons and steels	2,618
Brass and bronze	68
Ores	149
Sodium oxalate	281
Naphthalene	72
Benzoic acid	308
Sucrose	87
Dextrose	34
Metals for melting points	292
Cements for testing sieves	107

The decrease in the number of standard samples issued during the fiscal year is due to three causes: (1) When Congress failed in 1920 to appropriate for the standard sample work many purchasers feared that the work would be discontinued and therefore placed large orders before the close of the last fiscal year; (2) the lack of funds and equipment forced a heavy curtailment of the samples normally issued to colleges and universities; (3) the present depression in the industries is naturally reflected in a reduced demand for standard samples. In order that the needs of the industries and of educational establishments may be adequately met, the special fund formerly provided for this purpose should be restored and increased to $15,000. With this amount annually assured it would be possible to place the whole work upon a self-supporting basis. Certainly only a lack of understanding of the situation could have again led Congress to fail to provide an appropriation for work which brought to the Federal Treasury considerable funds, the fee value of the samples issued during the last three years having averaged almost $10,000 per year.

Three new samples were added to the list during the year—No. 51, electric furnace high-carbon steel; No. 52, cast bronze, and No. 53, lead-base bearing metal. Ten exhausted standard samples were renewed as follows: Iron C, 5d; iron E, 7a; Bessemer 0.4 carbon steel, 10c; Bessemer 0.8 carbon steel, 23a; nickel steel, 33a; chrome-nickel steel, 32a; copper, 45a; zinc, 43a; cement, 47c; and benzoic acid, 48a.

Cooperation in the Analysis of British Chemical Standards.

In addition to carrying on the analytical work dealing with the Bureau's standard samples, considerable analytical work was also done on the British chemical standards. In this work the Bureau cooperated with British, Scotch, French, and Italian analysts in the analysis of the British standard hematite cast iron "B," plain carbon steel "O1," carbon steel "M." and chrome-vanadium-tungsten-cobalt steel "W."

Cooperation in the Development of Standard Analytical Methods.

During the year the section cooperated with the American Society for Testing Materials in the development of standard methods for the analysis of aluminum, for the analysis of light aluminum alloys, and for the analysis of limestone, lime, and hydrated lime.

Researches in Progress.

A study of the Jones reductor with special reference to the reduction of iron, titanium, chromium, molybdenum, vanadium, and uranium has been completed as regards the first two, and the work dealing with the third is nearly finished. It is worthy of note that it has been found that titanium in any amount can be readily and completely reduced to the divalent condition, provided a few simple and readily met precautions are observed.

Another study embraces the determination of arsenic in irons and steels. Various methods have been studied and serious errors have been found in some. A modified accurate procedure is now being tested.

Still another study dealing with the composition of certain sulphides has been nearly completed. Several sulphides have been found to contain normally water of constitution, and certain others obtained in analysis, notably those of iron, cobalt, and nickel, have been found to possess quite different compositions than those ordinarily ascribed to them.

LUBRICATING OILS, RUBBER, PAPER, TEXTILES, INK, AND GLUE.

This section is concerned with chemical analysis and investigations of oils, rubber, paper, textiles, ink, glue, airplane dopes, etc., with special reference to meeting particular requirements.

Airplane Dopes.

The decrease in testing and investigation of airplane dopes that was commented on in last year's report as a result of the cessation of war activities was maintained during the past year.

Balloon Fabrics.

There was, however, no cessation in the routine chemical examination of rubberized balloon fabrics. Rubberized fabrics have a short life, and their permeability is greater than that of fabric covered with goldbeaters' skins. However, the skins are difficult to obtain in the enormous numbers needed, and their application is a tedious and expensive matter. An investigation was therefore started for the purpose of discovering some material having the desirable properties of the skins but which would be easier and less expensive to apply.

This problem was attacked from different directions, and some very encouraging results were obtained. A coated fabric of unusually low permeability was prepared. Exposure tests to determine its life are still in progress. Owing to the military value of the work, the results are not published in this report. In connection with this chief problem, work was done on other matters related to it but of somewhat less importance.

Rubber.

The routine testing of rubber goods continued to be very heavy, and much time was given to the preparation of specifications and further time to the study of analytical methods, the need for which is great because of the variety and complexity of mixtures used in rubber goods. A more complete account of the Bureau's work on rubber, including that of the Chemistry Division, is given on page 199.

Textiles.

Most of the work in textile chemistry had to do with the routine examination of rope, twine, flax, and asbestos packings, sized cloth, wool and cotton mixtures, and the testing of various dyed fabrics.

Some special work was done on absorbent cotton and on a large series of samples of haircloth intended for use in the production of cottonseed oil.

Of great interest was the examination of certain sealskins to determine how they had been dyed.

Writing and Copying Inks.

A great many writing and copying inks were analyzed and tested to guide the General Supply Committee, the Panama Canal, and the Post Office Department in making awards to contractors. Throughout the year many delivery samples were also tested.

It was noted a year ago that the use of concentrated inks and of ink tablets and powders was on the increase. Within the past 12 months fewer tablets and powders but more concentrated inks were tested than during the preceding year. For the ordinary user these present no particular advantage over writing fluid. Large users of ink, and especially those who distribute to branch offices from a central agency, save by needing less storage space, by lessened breakage from freezing and other causes, and by lower cost of shipment.

Black tablets and powders are not recommended for permanent records unless they contain the ingredients of an iron gallo-tannate ink of good quality and proper strength.

Stamping, Marking, and Related Inks.

Many samples of inks for use on stamp pads and duplicating machines, as well as inks for marking and stenciling, were examined. They were tested to find out whether they were suitable for the purposes intended.

Printing Inks.

Very few samples of printing inks were received for routine examination. However, a number were analyzed for the Public Health Service in order to find out, if possible, why inks of some colors cause dermatitis, while others have no bad effect upon the skin.

Typewriter and Similar Ribbons.

Large numbers of typewriter and similar ribbons were tested for awarding contracts and for checking deliveries. The ribbons were for use on typewriters and adding machines chiefly. The quality of the fabric and of the ink must be determined.

Carbon Paper.

Many samples of carbon paper were examined during the year. Among the factors to be considered are the thickness and quality of the paper, the amount and character of the coating, the permanence of the copy, its freedom from smudging, and the number of copies which can be made.

Glue, Mucilage, and Paste.

From time to time throughout the year samples of these materials, glue, mucilage, and paste, were tested.

Lubricants.

As has been the case for years a great many lubricating oils and greases were examined. The testing has been simplified by the practically universal adoption of the specifications and methods of the committee on standardization of petroleum specifications. Formerly when the specifications were more varied in character the testing laboratory was put to more trouble than at present.

The oxidizing effect of air upon petroleum oils is coming more and more to be recognized as something which can not be ignored and which should be considered in the laboratory. In addition to its influence upon the behavior of the oils in internal-combustion engines, oxygen is the cause of the formation of sludge in transformer oils. There are also indications that the deterioration of turbine oils is at least partly due to oxidation.

A study was made of a series of metals and their oxides, etc., in order to determine their effect upon the rate of oxidation of two typical oils. An account of this work will appear in the Journal of Industrial and Engineering Chemistry.

METALS, CEMENTS, BITUMINOUS MATERIALS, ETC.

The field covered by this section includes the chemical analysis of metals, among which may be mentioned iron, steel, nonferrous metals, alloys (such as brass, type metal, and solder), coated metals (such as tin plate and galvanized metals), lime, plaster, cement, concrete, and bituminous materials, including tars, asphalts, asphalt roofing papers, roofing felt, etc.

Built-Up Bituminous Roofing.

The term "built-up bituminous roofing" is applied to that type of roofing which is constructed on the job from successive layers of rag felt saturated with either asphalt or coal tar and cemented together either with asphalt or coal-tar pitch roofing cement. There are numerous types and different methods of constructing this roofing.

An investigation was made to determine the best materials and methods for constructing this type of roofing in order that specifications may be prepared for the use of the Government purchasers of these materials, architects, engineers, contractors, and the general public. This type of roofing is being used to an increasing extent, and requests for specifications have come from the Supervising Architect's Office, Panama Canal, and the War Department. The only specifications so far available have been those issued by interested manufacturers, so the importance of Government specifications is obvious.

This investigation included the field of inspection of roofs giving both good and poor service and which had been in service for from 3 to 46 years. One hundred and seventy typical jobs were selected and inspected from a list of approximately 700 roofs. These jobs were selected from different sections of the country in order to ascertain the effect of different climatic conditions upon similar materials and to determine the relative merits of different local methods of constructing similar types of roofs. Roofing conditions in the localities selected were also investigated and their bearing upon quality of the work turned out was noted. In addition to the jobs originally selected, roofs which were in the course of repair or construction and which were run into by chance were also inspected. Also in each locality visited a general survey of the roofing was made from the tops of high buildings and roofs selected for more careful inspection.

Detailed information on each roof was obtained, including the method of construction, date laid, and cost of maintenance, which information in all cases was verified from as many sources as possible.

Numerous samples were taken which have been examined in the laboratory. This information is now being arranged for publication as a technologic paper.

At the request of the Supervising Architect, which office is the largest Government user of built-up roofing, tentative specifications were prepared for asphalt and coal-tar saturated rag felts and asphalt and coal-tar pitch for use in constructing slag and gravel surfaced roofing on inclines not exceeding 2 inches to the foot. These specifications were submitted to manufacturers, roofers' and manufacturers' associations, and others interested for their criticisms and comments. Numerous criticisms and suggestions of merit were received which will be considered in the final draft of these specifications.

Prepared Roofing, Plastic Cement, and Roof Coating.

The specifications which were prepared for these materials last year were furnished recently to the Quartermaster General's Office for use in a $300,000 purchase of these materials for cantonment work. Numerous samples of these materials have been tested for this office.

Concrete Drain Tile.

An investigation has been started to determine whether concrete drain tile can be coated, impregnated, or otherwise treated with substances which are of themselves resistant to alkali waters and which will prevent the disintegration of concrete tile so protected and exposed in the alkali soil districts of the West. A number of tile have been treated with hot and cold asphaltic dips and have been exposed in this laboratory to 10 per cent solutions of sodium carbonate, sodium sulphate, and magnesium sulphate. No results as yet have been obtained.

Mastic Flooring.

At the request of the Supervising Architect's Office an investigation was undertaken to obtain information for the preparation of specifications for the material used for asphalt mastic flooring. Asphalt mastic is to be used as a substitute for maple flooring in the mail sorting rooms of post offices. Samples of materials from the three leading manufacturers have been examined to determine their composition and properties. Physical tests will have to be made and some performance tests developed for use in the specifications contemplated.

Black Ship Glues (Calking Pitch, Marine Glue).

At the request of the Panama Canal a number of samples of black ship glue were examined in order to obtain information for the preparation of specifications. This work is not completed.

Smokestack Paints.

A large number of samples of smokestack paints were tested for the Navy Department and the United States Shipping Board. This work required the development of a method for testing the heat resistance of these materials.

Belting Compounds.

In connection with Division VII–4 investigation of belting for the Post Office Department samples of saturating and coating compounds were examined to determine their composition. Most of these materials were nonbituminous in character and consisted of paraffin, light lubricating oil, rosin oil, raw and boiled linseed oil, oil paints, gutta balata, etc.

Lime Investigation.

Work on the investigation of methods of determination of available lime in quick and hydrated limes requested by the Interdepartmental Conference on Chemical Lime, which was mentioned as in progress in the report of the preceding year, has been completed. As a result of the work of the cooperating analysts of the Geological Survey, the Bureau of Chemistry, and the Bureau of Standards the conference agreed that none of the seven methods examined were satisfactory. Since of these methods, however, the Scaife method and the sucrose method gave some promise, investigations were continued by this laboratory. After determining the effect of variations in procedure upon typical lime samples a modified Scaife method was evolved which gave values sufficiently uniform for commercial purposes. Results obtained by the method in this laboratory have been corroborated by the Bureau of Chemistry. The modified method has been approved by the Interdepartmental Conference and incorporated in specifications to be published by the conference. The method has also been submitted to subcommittee V of committee C–7 of the American Society for Testing Materials, and is being investigated by the members of that committee. The work done has been summarized for publication.

Miscellaneous Work.

The Bureau has also been consulted by the Government and other departments on other problems connected with the use of bituminous materials. Some of these are the Nitrate Pit, at Savanna, Ill., the Lincoln Memorial Pool, and the roofing on the Interior Department Building, and on various buildings at this Bureau. In connection with an investigation of colorless waterproofing compounds (nonbituminous) under conduct of the cement section, samples of these materials are being examined. For the same division considerable work was done in several fields—analysis of alkali water and soil; waterproofing and floor-hardening compounds, sand and cement mixtures from the Johnson mixer; determination of the so-called supercement containing tannic acid; and a series of comparative analyses of various brands of Portland cement from Poland, Sweden, British Columbia, and elsewhere, which showed considerable difference in chemical composition compared with a representative type of American cement.

PAINT, VARNISH, AND SOAP.

This section is concerned with the chemical analysis, testing, and exposure tests of paint and varnish, as well as the chemical analysis of and specifications for soap.

Interdepartmental Committee on Paint Specification Standardization.

This committee, whose work was referred to in last year's report, has continued active and has now issued a sufficient number of specifications to be of decided use in general structural painting. New specifications will be added to this list from time to time, and the existing specifications will be revised as the need arises. It may be noted that not only have various branches of the Government service adopted many of these specifications but the American Society for Testing Materials will adopt certain of them and large users outside the Government are using some. Some manufacturers are making a point of advertising their goods as meeting these specifications.

CHEMICAL TESTING.

The number of chemical tests made in the chemical laboratories during the fiscal year was 7,941. Distributed by types of materials the tests were as follows: Ferrous metals (irons and steels), 664; nonferrous metals, alloys, and coated metals, 866; cement and cement materials, 1,071; bituminous products (including creosotes, etc.), 730; varnish materials (including shellacs), 426; paint materials, 733; lubricants, 373; soaps, nondrying oils, and metal polishes, 428; inks and related office supplies, 850; balloon fabrics, 266; rubber, 655; leather, 8; textiles, 479; miscellaneous, 392.

The tests were made for very many Government bureaus and establishments and for States, municipalities, and private parties, as follows: Agriculture, 7; Commerce, 4,044 (this includes samples received from other divisions of the Bureau for chemical tests); Interior, 22; Labor, 9; Navy, 246; Post Office, 380; Treasury, 426; War, 932; United States commissions and committees, 252 (including United States Shipping Board, 240); General Supply Committee, 668; Panama Canal, 845; other independent establishments, 60; State and municipal institutions, 26; private parties, 24.

PUBLICATIONS IN CHEMISTRY.

The following papers emanating wholly or in part from the Chemistry Division were published during the year:

1. Miscellaneous publication No. 46. War work of the Bureau of Standards.
2. Scientific Paper No. 390. The two common failures in the Clark standard cell.
3. Technologic Paper No. 180, Causes and prevention of the formation of noncondensible gases in ammonia absorption refrigeration machines.
4. Inflammability of jets of hydrogen, published in Jour. Indus. and Eng. Chem., 12, p. 1098: 1920.
5. The application of the thermal conductivity method to the automatic analysis of complex mixtures of gases, published in Jour. of Indus. and Eng. Chem., 12, p. 894; 1920.
6. Technologic Paper No. 190, Notes on black nickel-plating solutions.
7. Specification and inspection of electroplating for the automotive industries, published in Automatic Industries, 44, p. 1289; 1921.
8. The use of fluorides in solutions for nickel deposition, published in Trans. Am. Elec. Soc., 39, p. 227, and Chem. and Met. Eng., 35, p. 1109; 1921.
9. The preparation of pure platinum, published in Jour. Am. Chem. Soc., 43, p. 1268; 1921.
10. New deoxidizers for steel, published in Chem. and Met. Eng., 23, p. 879; 1920.
11. Determination of iron by the cupferron method, published in Jour. Am. Chem. Soc., 43, p. 847; 1921.

12. Circular No. 14, sixth edition. Analyzed irons and steels—Methods of analysis.
13. Circular No. 26. fourth edition. Analyzed iron and managanese ores—Methods of analysis.
14. Circular No. 40, third edition, Sodiuu oxalate as a standard in volumetric analysis.
15. Volatilization losses of phosphorus during evaporation of phosphates with sulphuric acid or fusions with pyrosulphate, published in Jour. Am. Chem. Soc., 42. p. 2609; 1920.
16. Determination of antimony in rubber goods, published in Rubber Age and Tire News, 8, p. 104; 1920.
17. Circular No. 38, fourth edition, The testing of rubber goods.
18. Technological Paper No. 177. Sulphur in petroleum oils.
19. Circular No. 99. The carbonization of lubricating oils.
20. Improved method for the determination of total sulphur in rubber. published in Rubber Age and Tire News, 9, p. 47:. 1921.
21. Technologic Paper No. 176. Slushing oils.
22. Circular No. 97. Recommended specifications for green paint—Semipaste and ready-mixed.
23. Circular No. 98, Recommended specifications for volatile mineral spirits for thinniug paints.
24. Circular No. 102. Recommended specification for composite thinner for thinning semipaste paints when the use of straight linseed oil is not justified.
25. Circular No. 103, Recommended specification for spar varnish.
26. Circular No. 104, Recommended specification for asphalt varnish.
27. Circular No. 105, Recommended specification for liquid paint drier.
28. Determination of cobalt and nickel in cobalt steels. published in Jour. Ind. and Eng. Chem., 13, p. 540; 1921.

The following are in preparation or in press:

Equilibria in the system carbon disulphide-methyl alcohol and carbon disulphide-ethyl alcohol.
Preparation of pure ammonia.
Vapor pressure of carbon dioxide.
Density and expansivity of sodium chloride solutions.
Technologic Paper No. 195, Zinc cyanide plating solutions.
Determination of aluminum as aluminum phosphate.
Quantitative precipitation by ammonia of phosphorus pentoxide with aluminum hydroxide.
Determination of molybdenum in steel.
Modified method for the determination of iron and vanadium after reduction by hydrogen sulphide.
Standardization of solutions employed in the evolution method for sulphur.
Notes on the analysis of the Bureau of Standards cast bronze No. 52.
Notes on the alkali-molybdate method for phosphorus in irons.
Catalytic oxidation of petroleum oils.
Determination of available quicklime an dhydrated lime.
Circular No. 111, Recommended specifications for flat interior lithophone paint—White and light tints.
Determiuation of the acid number of tung and other vegetable oils.

6. ENGINEERING PHYSICS.

Investigations relating to mechanics, sound, and properties of matter; testing and development of engineering instruments; performance standards of mechanical appliances; sound ranging; investigation of soundproofing properties of building materials; analysis and correction of acoustical defects of assembly rooms; elastic properties of diaphragms and springs; investigation, testing, and experimental development of aircraft instruments; ballistics; aerodynamical testing and research.

GENERAL.

The Engineering Physics Division includes sections dealing with (1) engineering instruments and mechanical appliances, (2) sound investigations, (3) aeronautic instruments, and (4) aerodynamical physics. In addition special experimental and theoretical researches

are carried on by a staff of engineering physicists. The activities of the division in testing and research are described in the following pages. A less tangible but equally important feature of the work is to be found in the advisory relationship which has been developed with other technical branches of the Government and with the industries. This is illustrated by the participation by the Bureau (1) in the formulation of several of the power test codes of the American Society of Mechanical Engineers and in the work of the A. S. M. E. fluid meters research committee; (2) in the work of the aerodynamics committee of the National Advisory Committee for Aeronautics; and (3) in numerous conferences with representatives of the Army and Navy, particularly in connection with problems in aerodynamics and ballistics.

ENGINEERING INSTRUMENTS.

Current-Meter Rating Station.

The accurate calibration of water current meters used in measuring the discharge of rivers and other open channels requires equipment too extensive and costly to be provided by private enterprise. A hydraulic laboratory, designed and equipped especially for this purpose and housed in so as to be available throughout the year, is maintained by the Bureau to supply this necessary service. During the past fiscal year 279 current meters of various types were calibrated for the engineering bureaus of the Government, instrument manufacturers, and engineers in private practice.

Calibration of Instruments.

During the past fiscal year 511 instruments were tested, including current meters, pressure gauges of various descriptions, anemometers, water meters, speedometers, steam-engine indicators, and miscellaneous engineering instruments.

Hydrogen Cylinder Valves.

At the request of the office of the chief of Air Service of the Army experiments were undertaken to secure a more reliable high-pressure gas valve for use on hydrogen cylinders. A series of comparative tests under conditions approximating those occurring in service were made of the valve now used and a number of other types, resulting in the selection of a design which promises to meet satisfactorily the requirements, both as regards tightness and durability.

Safety-Release Device for Hydrogen Valves.

The investigation of hydrogen valves has been extended at the request of the Air Service to include a study of the safety-release device which forms a part of these valves. The function of this device is to safeguard the cylinder against explosion if dangerous pressures are developed within the cylinder by reason of their being accidentally exposed to high temperatures. The gradual yielding of the safety-release device now in use under continued pressure and its consequent discharge under ordinary service conditions has occasioned an appreciable loss of gas. Experiments are now in prog-

ress to secure data for the specification of a device which will correct this condition, if possible, without important changes in the present equipment.

Radiator Return Line Valves.

The Bureau has in the past few years made numerous performance tests of the automatic valves used at the outlet of radiators in vacuum-heating systems to remove water of condensation and air and to prevent the passage of uncondensed steam. These tests have been made at the request of the Office of the Supervising Architect of the Treasury Department for its guidance in approval of equipment of this character for use on projects under its control. Valves of this type play such an important part in the successful operation of vacuum-heating systems that the Bureau has recently undertaken a series of tests of a number of representative brands collected in the open market to determine what standard of performance is attained in the commercial production of these appliances and what performance may reasonably be required. It is proposed to publish the general results of these tests in the near future.

Air Measurements of Vacuum Cleaners.

It is the trade practice to express the performance of vacuum cleaners in terms of (1) the vacuum developed at the tool and (2) the volume of air exhausted by the machine in a given time. No uniform method of making these measurements has been in use, with the result that the values given for these quantities by the different manufacturers are not comparable. At the request of the Vacuum Cleaner Manufacturers' Association a standard procedure has been developed which will reduce the ratings to a comparable basis.

Fire Extinguishers.

The investigation and testing of fire extinguishers was inaugurated at the Bureau several years ago for the guidance of the Steamboat-Inspection Service in its approval of equipment of this character on vessels under its jurisdiction. Twelve such devices, involving in some instances new principles of construction and operation, were examined during the year.

Miscellaneous Engineering Tests.

A number of miscellaneous tests of appliances were made, such as hydrostatic tests of cylinders and other containers, examinations and tests of air pumps, valves, and similar appliances.

SOUND MEASUREMENTS.

The principal obstacle in the investigation of scientific and industrial problems in sound is the lack of suitable measuring instruments. It has, therefore, been necessary to develop a number of instruments for quantitative sound measurement in the sound laboratory.

Sound Source.

A portable electromechanical sound source has been devised which can be used for sound measurements under most conditions encountered in practice. It consists of a specially designed electron-

tube oscillator, together with an electromechanical output instrument of the loud-speaking telephone type. Practically the entire audible frequency range is covered by this instrument, and wide latitude of intensity is available. The purity of the sound output under various conditions has been carefully studied. This instrument has rendered valuable service in connection with sound-reflection measurements.

Intensity Measurements of Sound.

Many of the instruments used in measuring sound intensity at any frequency, such as the Raleigh disk or the Webster phonometer, can not readily be changed from one frequency to another over a wide range. An apparatus possessing this desirable feature has been constructed, the apparatus being a development of that devised by Prof. G. W. Pierce. A telephone receiver is used as the receiving element, and a crystal detector-galvanometer circuit forms the essential indicating element. In order to increase the intensity range of the instrument, two stages of electron-tube amplification have been introduced, one or both of which may be used according to the requirements of the problem.

The Sound Field of a Parabolic Mirror.

The sound source and intensity measuring devices described above have been used to study the sound field of a large parabolic mirror used by the United States Army for locating aircraft by sound. Measurements have been made of the distribution of intensity and of phase, and data have been obtained which will aid in the efficient design of parabolic mirrors for various acoustical purposes.

Radiation Detector for Airplanes.

During the war a system of detecting airplanes by their heat radiation was in process of development. The image of the plane was focused on a sensitive thermopile by means of a parabolic mirror. The indicating device first used was a galvanometer of extremely high sensitivity. The practicability of using such an instrument in the field was seriously questioned. An indicating system, consisting of suitable amplifiers and current reversers, was developed in the sound laboratory by means of which the heat radiation is indicated by an audible signal in a telephone. The electromotive force generated in the thermopile is first amplified several thousand times by a direct-current amplifier, then reversed without interruption at suitable frequency and the periodically reversed current amplified by a suitable audio-frequency amplifier, to the output of which the telephone is attached. Adequate sensitivity is obtained in this way.

Building Acoustics.

A large number of inquiries have been received from proprietors of buildings, manufacturers of building materials, contractors, and architects for information concerning the acoustic aspects of building materials and modes of construction. It has been possible to give only limited assistance in this matter, as, in many instances, the data required do not appear to be in existence. The volume and character of these inquiries serve to emphasize the need of a well-considered

program to develop the necessary information, a program involving a comparative study of all materials and modes of construction prevalent in the present-day building industry.

Aside from the development of measuring instruments, little progress was made during the year in the work related to building acoustics. This kind of work requires laboratory space of special character. So far space has not been available which satisfies these requirements, even approximately, but plans have been developed for a system of sound chambers which, while modest in proportion, will make progress along this line possible. The execution of these plans is now under way.

The Electron-Tube Drive of Tuning Forks and Other Apparatus.

The electron-tube drive of tuning forks developed last year has been considerably improved, the electric and magnetic circuits now used making the operation of the fork simpler and the apparatus more available for general use. The double-slit method of obtaining time indices from the tuning fork has been discarded in some cases and a tuned vibrator operated by the current from the plate coil of a fork has been used to obtain the required time index marks on films. The technique of the measurement of small-scale time intervals has been simplified considerably in this manner. During the year the electron-tube drive was successfully applied to the maintenance of the vibrations of a Webster phone.

The work done by the sound laboratory in developing the use of the tuning fork for the measurement of small-scale time intervals has led to a number of applications to which the staff of the laboratory has devoted the major portion of its energies during the year just closed.

Radio Time Recorder.

An instrument for recording radio signals, specifically time signals, was developed for the Coast and Geodetic Survey. This instrument is sufficiently rugged and the incidental equipment is sufficiently light to make it available for field use. It is to be used for the determination of precise longitude of any field station with reference to that of a standard time-transmitting station, such as Annapolis. Radio messages have been recorded with success from European stations with the use of only a single tube of the receiving type. The chronographic apparatus is so designed that the lags in the recording apparatus are minimized, local and radio signals being recorded by the same pen.

The recorders for the longitude work are designed for long-wave lengths. A short-wave recorder has been designed for use in connection with ballistic measurements on aircraft bombs.

Solenoid Chronograph.

In cooperation with the technical staff of the Ordnance Department, United States Army, especially with Maj. G. F. Hull, a chronograph has been developed for the very precise measurement of projectile speeds over small distances. Magnetized projectiles are fired through suitably placed coils. The coils are all in series and are connected to an oscillograph element through a transformer.

During the passage of a shell through a coil a deflection of the oscillograph element is obtained and the sequence of such deflections on a moving film, together with a suitable time scale, yields the time intervals required. Proper coordination between the firing of the gun and the operation of the chronograph has been provided.

Some preliminary work has been done on securing other than photographic recording with the solenoid coils, but definite results of this work can not be reported at this time.

Several commercial oscillographs have been designed and reconstructed for use in various research problems at the Army proving grounds at Aberdeen, Md.

Piezo-Electric Pressure Gauge.

Paralleling the work on the solenoid chronograph, the feasibility of utilizing the piezo-electric effect for obtaining a graphical record of the time pressure relation in a discharging gun has been investigated. A method utilizing a ballistic galvanometer as the indicating instrument has been developed, and preliminary results have been obtained of explosions in a pressure bomb which indicate that the method is a promising one. Calibration is effected on a testing machine. If the gauge is properly designed, the quartz, which is the piezo-electric material used, can be safely subjected to practically the full pressure in the gun. However, a small reducing factor is provided in the gauge. The gauge is practically free from temperature errors, a calibration at 100° C. agreeing within the error of measurement with that made at room temperature.

Sound Ranging.

The sound laboratory has worked in cooperation with the Signal Corps and the technical staff, Army Ordnance, on various phases of sound ranging. For the latter organization the section is engaged in the development of a sound-ranging equipment on the small-arms range at the Aberdeen Proving Grounds. The purpose of this installation is to get ballistic data from machine-gun firings by sound-ranging methods.

String Galvanometer.

In connection with this and other problems the provision of adequate damping of the string galvanometer systems used in artillery sound ranging during the late war has been investigated. An improved form of string galvanometer in which the strings are immersed in a suitable damping liquid has been developed as a result of these experiments.

Oscillograph Element Without Damping Fluid.

When high-speed records are to be obtained, the presence of the damping fluid in the standard type of oscillograph element involves a loss of light which makes the securing of good records very difficult. Following up a suggestion made in the Electrical Division of the Bureau, adequate damping without the use of a damping fluid has been secured by backing the vibrator with a narrow strip of aluminum about 2.5 mils thick, applied symmetrically with respect to the mirror and the vibrator strip. The window of the cell usually

containing the element can be eliminated in this way, and adequate eddy current damping is obtained if the aluminum strip is suitably dimensioned.

AERONAUTIC INSTRUMENTS.

The aeronautic instruments section has been engaged in an extensive program of research and development work on aircraft instruments in cooperation with the Army, the Navy, the National Advisory Committee for Aeronautics, and to a more limited extent with other Government agencies and private concerns. Besides experimental investigations and the development of new instruments a considerable amount of routine work on instruments submitted for tests has also been carried out.

The development work may be considered under two heads; first, the experimental investigations, which deal with the fundamental physical principles involved in instrument design, and second, the practical design and construction of new types of aircraft instruments.

Altitude Effect on Air-Speed Indicators.

An investigation of the altitude effect on air-speed indicators has been completed and the results have been published in a report by the National Advisory Committee for Aeronautics. This investigation shows that Venturi tubes when used as air-speed pressure nozzles deviate considerably at low-air speeds and low-air densities from the ρV^2 law which is usually assumed throughout the range of aircraft speeds. Attention was called to this effect in last year's report, but at that time, owing to limited experimental facilities, only qualitative data were available. During the past year a wind tunnel with a 16-inch throat has been constructed and mounted in one of the Bureau of Standards altitude chambers. Air speeds up to approximately 100 miles per hour were attained in this tunnel under conditions of pressure and temperature corresponding to any desired altitude up to 30,000 feet, and the following nozzles were examined: United States Navy, United States Army, and Toussaint-Lepere Pitot-Venturi nozzles, Badin single and double Venturi nozzles, and the Bruhn double Venturi nozzle. Tables and charts of the altitude correction for these nozzles to supersede the former corrections which involve air density alone are in preparation.

Diaphragm Investigation.

Research in connection with the improvement of instrument diaphrams has been continued along the following lines: (*a*) The laws of deflection for corrugated metallic diaphragms have been determined experimentally. The results will facilitate the work of designing suitable diaphragms to conform to specific conditions of use. (*b*) Means of computing the effective force of diaphragms—that is, the force available for performing useful work—have been developed for both sylphon diaphragms and slack diaphragms. From the geometrical shape of the diaphragm and the magnitude of the fluid pressure the designer can immediately predict the effective force for any deflection. (*c*) Temperature and porosity tests have been carried

out on a number of rubberized fabrics, doped fabrics, and thin leathers to determine their suitability for use as slack diaphragms.

Hysteresis in Bourdon Tubes.

Tests for elastic lag and hysteresis have been made on Bourdon tubes. These tests were made over a pressure range of from 0 to 80 pounds per square inch and a temperature range from 0 to 50° C. The results as indicated by the limited number of tubes tested show that the elastic lag and hysteresis of Bourdon tubes is approximately the same in amount as that found in aneroid diaphragms.

Bimetallic Bars.

Tests have been carried out on flat and coiled bimetallic bars to determine the character of the deflection with change of temperature and also to study the elastic lag and hysteresis. The deflections were found to be linear over a range of temperature of from +25° C. to —40° C., and the hysteresis and temperature lag effects were small. Such bars are capable of developing sufficient force to operate the temperature-compensating mechanism in aeronautic instruments.

Aircraft Sextants.

In connection with the development of an improved type of aircraft sextant extended tests of available types have been carried out. Attention has been particularly directed to a study of the optical systems and to accuracy and convenience in use. Methods of obtaining an artificial horizon have been investigated to determine the best form for aircraft sextants.

Aircraft Compasses.

An extensive study of all available types of aircraft compasses and of the literature on the subject has been made in connection with the development of a new type of compass. An extended investigation of the Bamberg distant reading compass was made both in the laboratory and in flight.

Turn Indicators.

An investigation of aircraft turn indicators has been recently undertaken at the request of the Army. A survey of existing instruments has been made, and laboratory and flight tests have been conducted on available types of turn indicators with a view to the development of a new instrument.

Precision Barometer.

An improved model of precision barometer has been developed and the laboratory tests indicate a satisfactory performance. The design is based on the same principle used in the earlier model, namely, that of using a relatively flexible diaphragm in conjunction with a stiff spring carefully selected as to its elastic qualities. The spring was heat treated by the Metallurgical Division of the Bureau. The pointer of the instrument makes two and one-half revolutions over the dial. To avoid confusion in reading the instrument, an automatic dial-shifting device has been devised to change the dial numbers when the pointer makes more than one complete revolution.

Temperature Compensated Altimeter.

This instrument consists of a Bureau of Standards precision altimeter combined with a temperature compensating element. Variation of altitude reading with change in the temperature of the atmosphere is automatically corrected on the assumption that the average temperature of the air column from the ground to the instrument is equal to the arithmetic mean of the temperatures at the ground and at the position occupied by the instrument.

Precision Barograph.

A precision barograph incorporating a sylphon diaphragm and a specially heat-treated coiled internal spring is now under construction. This instrument will have a novel recording device which permits the use of a chart with rectilinear coordinates instead of the curved time scale ordinarily used.

Rate-of-Climb Indicator, Model No. 3.

Ten instruments of this type have been designed and constructed under the supervision of the Bureau for the use of the Army.

Recording Rate-of-Climb Indicator.

In airplane performance tests it is often desirable to have a permanent record of the rate of climb. Recording apparatus of this type has been designed and constructed for the Navy. The instrument consists of a rate-of-climb indicator of the capillary leak type with sylphon diaphragm. A record of the deflections of the diaphragm is obtained by reflecting light from a small mirror onto a light-sensitive chart attached to a revolving drum.

Combined Statoscope and Rate-of-Climb Indicator.

The purpose of this instrument, which consists essentially of a Bureau of Standards rate-of-climb indicator model No. 3 combined with a bubble statoscope, is to provide in the same instrument a sensitive detector of slight changes of level and a less sensitive quantitative indicator of rates of ascent or descent. By turning a thumbscrew in the case of the instrument it can be used either as a statoscope or as a rate-of-climb indicator. This instrument has been completed and delivered to the Army.

Ground-Speed Indicator.

At the request of the Balloon and Airship Division of the Army a ground-speed indicator for free balloons of the three-point sight type was designed and constructed for use in the recent official balloon race at Birmingham, Ala.

A ground-speed indicator of the optical synchronizing type has been designed and practically completed. This instrument consists essentially of a hexagonal glass prism which is rotated about an axis perpendicular to the direction of motion of the aircraft relative to the ground. The rate of rotation of the prism required to make objects on the ground appear to remain at rest is a measure of the ground speed if the altitude is known. The instrument is so designed as to read directly the ground speed in miles per hour by means of a tachometer attached to the rotating prism. Altitude

adjustment is provided so that the instrument can be set to read correctly at any altitude.

Sextants.

Designs for a new type of aircraft sextant have been prepared and submitted to the Army. This device differs radically in form from the marine sextant. A bubble horizon is attached, and a single rotating mirror is provided. This mirror is turned by a worm and wheel suitably graduated, thereby eliminating the large sextant scale ordinarily used. A method of varying the size of the bubble to compensate for temperature changes has been incorporated. Electrical illumination of the bubble and scales is provided.

Astronomical Position Finder.

It has been proposed to determine the position of aircraft at night from any two known celestial objects, such as two stars and the Greenwich sidereal time. An experimental model of an optical instrument of this type is now under consideration. This instrument provides a means for determining the altitude of the pole and the hour angle of the two celestial objects chosen and consists essentially of a telescope and two mirrors rotatable so as to reflect the light of the two objects chosen into the telescope. The mirrors are each independently rotatable about the axis of the telescope and about an axis at right angles to the telescope. A bubble horizon is used.

Horizontal Angle Indicator.

An instrument for measuring horizontal angles from captive balloons was submitted by the Balloon and Airship Division of the Army for test and investigation. Several changes were made which simplified the instrument and increased its range. The various optical methods which may be used in an instrument of this type have been studied and a second model embodying the most promising optical combination has been designed.

Tachometers.

The results of tests on an experimental model of a centrifugal tachometer of the double-inclined weight type have been incorporated in the design of a new instrument. A circular spring type of centrifugal tachometer, extremely simple and with few moving parts, has been tested and found to give promising results. An instrument of this type is being designed.

Air-Speed Indicator for Dirigibles.

The development of an air-speed indicator having a range of from 10 to 80 miles per hour for use on dirigible balloons has been undertaken and a model instrument completed. After a study of the possibilities of the ordinary differential pressure type of air-speed indicator, the pressure-plate type, anemometer type, and hot-wire type, the cup anemometer was selected as the most suitable for the conditions. It was necessary to employ some means of transferring the motion of the anemometer to the instrument board without putting an appreciable load on the anemometer. This was done by attaching to the anemometer a specially constructed commutator which auto-

matically charges a condenser and discharges it through a sensitive galvanometer at rapid intervals proportional to the rate of revolution of the anemometer. The effective current and consequently the deflection of the galvanometer is proportional to the speed of the anemometer.

Ballonet Volume Indicator for Dirigibles.

The purpose of this instrument is to indicate the volume of air contained in the ballonets of nonrigid dirigible balloons. Actual tests carried on inside the ballonet of a nonrigid airship at Langley Field showed that the mechanical type of indicator which had already been tried was less promising than an instrument depending upon the static pressure of the air in the ballonet. The design of a volume indicator of the latter type is now in preparation.

Compasses.

Results of the investigation of compasses have been applied in the design of a new type of double-pivot liquid-damped compass. A model of the instrument has been nearly completed.

Standard Testing Sets for Field Use.

At the request of the Navy standard sets of aeronautic instruments have been made for field use in the comparison and calibration of service instruments. These sets consist of high and low range altimeters, air-speed indicators, and thermometers, a tachometer, clock, and record pad. Selected instruments were carefully calibrated for these sets. Carrying cases are to be provided.

Foreign Representative.

Pursuant of the policy of following the latest developments in aeronautic instruments in foreign countries a member of the section has been detailed abroad during the last three months of the year. Special attention was given to lighter-than-air craft instrument development in England, France, Italy, and Germany. This work has been carried on in cooperation with our military, naval, and commercial attachés. Much valuable information has in this manner been placed at our disposal, and in reciprocation information in regard to recent investigations at the Bureau of Standards has been made available to foreign officials interested in aeronautic instrument development.

Instrument Collection.

Further additions have been made during the year to the collection of aeronautic instruments which is maintained by the Bureau of Standards. Sixty-five new instruments have been acquired by purchase abroad, from local manufacturers, and by loan from other departments of the Government. These include electric and air-driven gyroturn indicators, ordinary and distant reading compasses, chronometric, centrifugal, and electric tachometers, liquid oxygen apparatus, air-speed indicators, air-distance indicators, statoscopes, barographs and thermographs, gasoline flow meters, accelerometers, electric thermometers, gasoline level gauges, and pressure gauges.

Routine Testing.

While the major part of the work of the aeronautic instruments section during the past year has been devoted to the development of new types of instruments, a considerable amount of routine testing has been done for different departments of the Government and private concerns. This includes 62 aneroid barometers, 3 surveying aneroids, 1 pocket aneroid, 3 mercurial barometers, 2 high-altitude barographs, 1 weather barograph, 3 thermographs, 1 hydrograph, 13 air-speed indicators, 26 tachometers, 6 gyro turn indicators, 4 sextants, 1 horizontal angle indicator, 2 balloon manometers, 1 gas-pressure manometer, 4 inclinometers, 18 instrument-board thermometers, 16 strut thermometers, 43 sphygmomanometers, 1 airship slide rule, 2 propeller pumps.

Flight Tests on Aeronautic Instruments.

The successful development of new types of aeronautic instruments requires that they be tested in flight in the course of development. This need has been fulfilled through the courtesy of the Army and Navy, who have arranged to place at the disposal of the Bureau aircraft for the testing of the instruments which have been under development. Eighteen flights have been made in airplanes, seaplanes, and dirigibles, and experiments have also been carried out in captive balloons.

AERODYNAMICAL PHYSICS.

Two wind tunnels are now available at the Bureau for aerodynamical work and a third is under construction. The tunnels differ in size and speed range and are adapted to a great variety of work.

The 54-inch tunnel, located in the wind tunnel building, is of the N. P. L. type, octagonal in cross section, the 54-inch dimension being between opposite faces. The faired entrance of the tunnel is about 4 feet long, the parallel portion 25 feet long, and the exhaust cone 15 feet long. The diameter at the propeller end is 9 feet. The tunnel room is 68.4 feet long, 28.5 feet wide, and 18 feet high. The room is divided transversely near the exit end of the tunnel by a wall honeycomb, consisting of pasteboard tubes 1.5 inches in diameter and 4 inches long, packed in a light framework, which is covered on both sides by mosquito bar. This open honeycomb structure serves to damp out the swirl and eddies in the air stream as it returns from the fan to the tunnel entrance. A speed range of 17 to 90 miles per hour is attained in the tunnel with the expenditure of from 2 to 90 horsepower. Two balances are available, the first being a modified N. P. L. balance with an auxiliary balance for pitching moments, used chiefly for work on aerofoils and airplane models. The second balance is designed for very heavy models, such as radiator sections, engine cylinders, etc., and is adapted chiefly to head-resistance measurements. For very accurate work at low speeds storage-battery current may be used.

The 36-inch tunnel, located in the northwest building of the Bureau, is of the Venturi type, circular in cross section. The entrance cone is 12 feet long, the working portion 6 feet long, and the exit cone 33 feet long. The diameter at the end of the exit cone and the front of the entrance cone is 7 feet. The tunnel room is 106.7

feet long, 25.2 feet wide, and 10.2 feet high. Two wall honeycombs, consisting of hollow tile covered with mosquito bar, extend entirely across the room in the path of the returning air stream. A speed range of 11 to 180 miles per hour may be attained in this tunnel with an expenditure of from 1 to 110 horsepower. Speeds over 150 miles per hour may be maintained for short intervals of time only. This tunnel is steady and relatively free from turbulence. A balance of a modified N. P. L. type is under construction, but deflection methods have been much used in the past. The tunnel is well suited to the calibration of airplane instruments at airplane speeds and to the investigation of devices functioning in a wind stream of high speed.

The third tunnel, which is now under construction, will be 10 feet in diameter and will not be housed. A speed range equal to that of the 54-inch tunnel is expected, with an expenditure of 250 horsepower. The tunnel, circular in section, will consist of a straight part 50 feet long and an exit cone 34 feet long, 14 feet in diameter, at the propeller end.

Apparatus is thus available for practically all kinds of aerodynamic testing except propeller and windmill torque and thrust measurements.

Aerodynamical Characteristics of Aircraft Bombs.

The aerodynamical physics section has been working for the past two years in close cooperation with the Aircraft Armament Division of the Ordnance Department, United States Army, on problems connected with aerial bombing. During the first part of the year a report was prepared in which the results of all previous wind-tunnel tests on bomb models were analyzed and compared. As a result of this study, and in view of the limited number of forms included, the Ordnance Department felt that a comprehensive investigation of a large number of bomb forms should be undertaken.

The general investigation is now well under way. The Ordnance Department furnished an exceptionally good collection of aluminum models of ogives and bodies from which a large number of bomb forms could be built up. A convenient and accurate deflection method of measuring head resistance was developed by the wind-tunnel staff, and a new oscillating apparatus was designed and constructed. A large number of tests have been conducted, the results of which give a new conception of the relative importance of the various elements of bomb design.

The Bureau has also cooperated with the Ordnance Department in tests at the Aberdeen Proving Ground on service bombs dropped from an airplane. The method used, which was devised by Maj. F. C. Brown, requires a series of photographs of the falling bomb over a body of water, which are taken from the airplane with the aid of a special moving-picture camera. A vertical reference line through the airplane is determined by the position on the film of the image of the reflection of the airplane on the body of water. Landmarks are anchored on the water at known distances apart, the images of which on the film serve to determine the measurement of ground speed and the height. The camera points down from the airplane and is focused for distant objects. On a part of the film there is focused, by means of a camera lens and a mirror, the image of a stop watch. The camera

is located a little to one side of the center of gravity of the bomb, so that the film shows the airplane reflection, the landmarks, the bomb, and the watch. The work of the Bureau in connection with these tests consisted in the measurement and interpretation of the films obtained.

Suitable reflections have been difficult to secure, and the Bureau has assisted the Ordnance Department in the planning of a supplementary method in which cameras obscura are used. Two cameras are to be employed. One points vertically upward, and the other, located at the end of a measured base line, points at a vertical angle toward the first. The bomb is to be released over the vertical camera, its position on the plotting boards being dotted in for some seconds just prior to the release. The time of fall of the bomb is to be measured by a special chronograph, the signal at release being given by wireless. The Bureau is constructing a special receiving set and other minor equipment necessary for this work.

Investigation of Flow Around Wind Screens.

In cooperation with the Balloon and Airship Division of the Air Service an investigation is being made of the flow around the wind screens which are used for the protection of dirigibles when entering and leaving their hangars in cross winds. A solid screen is objectionable for this purpose on account of the violent eddying motion produced on its lee side. The problem is to design a screen which will give the greatest reduction in the wind speed with the least eddying.

Wind-tunnel tests have been carried out on various types of perforated screens, on the basis of which a recommendation has been made to the Balloon and Airship Division for screens for immediate use. The wind-tunnel work is now being supplemented by outdoor measurements of the forces on a one-twentieth scale model of a standard type dirigible when located near the entrance to its hangar and protected by various types of screens.

Resistance of Spherical Bodies.

Further measurements have been made of the air resistance of spherical bodies of various types. The importance of such measurements lies in the fact that the flow about spheres is very sensitive to conditions of turbulence in the air stream. Hence, the turbulence which has an appreciable effect on the air resistance of cylinders, spheres, thick wing sections, etc., may be qualitatively studied by studying the resistance of spheres under various conditions.

Through a certain range in air speed the effect of turbulence is to reduce the air resistance of a sphere. Furthermore, turbulence may be produced simply by roughening the surface of the sphere. Incidentally, these facts find an interesting application to golf balls. Wind-tunnel measurements show that the roughened ball has less head resistance than a smooth ball for speeds corresponding to those prevailing during the flight of a swiftly driven ball, so that it should be possible to drive a ball with a roughened surface farther and faster than a smooth ball of the same size and weight.

Pilot balloons are used to explore the air currents in the upper regions of the atmosphere. It is of importance to know their head resistance. The results of wind-tunnel tests show a general agree-

ment of the coefficients with those obtained for smooth spheres. However, the results do not check numerically with those calculated from the observed rate of ascent of the balloon in the open air. The discrepancy is a comparatively large one, and no explanation has as yet been found. In general, the effects of turbulence are of primary concern in the interpretation of wind-tunnel data, and any failure in the application of wind-tunnel results to free-air conditions should be thoroughly investigated.

Ventilation Problems.

Toward the end of last year the Bureau undertook, at the suggestion of the American Society of Heating and Ventilating Engineers, the investigation of roof ventilators. This investigation was carried out in the laboratory where conditions were under control, and, although all conditions of practice were not typified by the installation, comparative results were obtained. The results of the investigation were presented before the society at their annual meeting and aroused considerable interest. The Bureau plans to issue a technologic paper on the subject.

Testing of Instruments and Airplane Models.

The usual routine testing of airfoils, airplane models, anemometers, and other instruments has required a part of the time of the wind-tunnel staff. The tunnels were also used in developmental work in cooperation with the aeronautic instruments section and a study was made, in cooperation with the engineering instruments section, of the swirl correction of the whirling arm used for anemometer testing and of the interference effects of various anemometer mountings.

PUBLICATIONS.

The following papers from the Division of Engineering Physics have been published during the year:

Notes on small-flow meters for air (E. Buckingham), Tech. Paper No. 183.
On the use of models in investigating the resistance of ship structures to external explosions (E. Buckingham), Jour. of the Am. Soc. of Naval Engs., May, 1921.
Notes on the use of dimensional reasoning (E. Buckingham), Phil. Mag., 1921.
Some comparative tests of 16-inch roof ventilators (H. L. Dryden, W. F. Stutz, and R. H. Heald), Jour. Am. Soc. of Heat. and Vent. Eng., March, 1921.
The altitude effect on air-speed indicators (M. D. Hersey, F. L. Hunt, and H. N. Eaton), Rep. No. 110, National Advisory Committee for Aeronautics, 1921.
Sphygmomanometers (J. L. Wilson and H. N. Eaton), B. of S. Cir. (mimeographed).

The following papers have been accepted by the National Advisory Committee for Aeronautics for publication in their annual report for 1921:

General classification of instruments and problems (M. D. Hersey).
Altimeters and barographs (A. H. Mears, H. B. Henrickson, and W. G. Brombacher).
Precision altimeter design (J. B. Peterson and J. R. Freeman, jr.).
Statoscopes and rate-of-climb indicators (A. H. Mears).
Aerographic instruments (J. A. C. Warner).
Air-speed indicators (F. L. Hunt).
Testing methods for air-speed indicators (H. O. Stearns).
Principles of ground-speed measurement (F. L. Hunt).

Inclinometers and banking indicators (W. S. Franklin and M. H. Stillman)
A new form of gyrostabilizers (W. S. Franklin).
Aircraft compasses and turn indicators (J. A. C. Warner).
Testing of magnetic compasses (R. L. Sanford).[1]
Aircraft tachometers (G. E. Washburn).
Testing methods for tachometers (R. C. Sylvander).
Thermometers for aircraft engines (E. F. Mueller and R. M. Wilhelm).[2]
Air-pressure and oil-pressure gages (H. N. Eaton).
Gasoline-depth gages and flow meters (J. A. C. Warner).
Oxygen instruments (F. L. Hunt).
Navigating instruments (H. N. Eaton).
Recent developments in aeronautic instruments (F. L. Hunt).

The following papers have been presented before technical and scientific societies:

A portable sound producer of considerable range as to frequency and intensity (E. A. Eckhardt), Am. Phys. Soc., December, 1920.
The sound field of a parabolic mirror (E. A. Eckhardt), Am. Phys. Soc., December, 1920.
Apparatus for measuring sound intensity (J. C. Karcher), Am. Phys. Soc., December, 1920.
A method of measuring phase differences in a sound field (J. C. Karcher), Am. Phys. Soc., December, 1920.
Some comparative tests of 16-inch roof ventilators (H. L. Dryden, W. F. Stutz, and R. H. Heald), Am. Soc. of Heat. and Vent. Engs., January, 1921.
Wind tunnels and their uses (L. J. Briggs), Washington section of Am Soc. of Mech. Engs., January, 1921.
Measurement of air resistance on projectiles in actual flight (E. A. Eckhardt), Washington section Am. Soc. of Mech. Engs., January, 1921.
Electron-tube drive for tuning forks (E. A. Eckhardt, J. C. Karcher, and M. Keiser), Am. Phys. Soc., February, 1921.
A high-speed oscillograph camera (E. A. Eckhardt), Am. Phys. Soc., February, 1921.
A chronographic recorder of radio time signals (E. A. Eckhardt and J. C. Karcher), The Philosophical Society of Washington, March, 1921; Am. Phys. Soc., April, 1921.
The determination of instantaneous pressures in guns by means of a piezoelectric gage and a ballistic galvanometer (J. C. Karcher), Am. Phys. Soc., April, 1921.

7. STRUCTURAL, ENGINEERING, AND MISCELLANEOUS MATERIALS.

This division is concerned with the investigation of the properties, uses, design, and fabrication of structural, engineering, and miscellaneous materials. This includes metal of all kinds and wood, especially when fabricated into structures or structural parts, cement, concrete, lime, gypsum, sand, stone, and sand-lime brick. Under miscellaneous materials are included leather, rubber, and composition materials used in place of these, textiles, paper, and lubricating oils. To make the study of these products complete, it is desirable to take into consideration the processes by which they are manufactured. Hence, the equipment includes an experimental rubber mill, textile mill, paper machine, cement plant, etc. The division is also concerned in the improvement of the present and the developing of new methods of testing and the development of standards covering the use of the materials concerned.

PHYSICAL TESTS OF STRUCTURAL MATERIALS.

General Scope of Work.

During the recent war many tests of materials and equipment were made as quickly as possible to assist the military service in placing contracts. Often these were of such a nature that they were of permanent technical value. At present these laboratories are making

[1] Contribution from the Electrical Division.
[2] Contribution from the Heat Division.

similar tests for the military and other branches of the Government, but the number has greatly decreased. Opportunity is therefore presented to carry on work of a character which will be of value to engineers and others engaged in technical and industrial lines. The equipment of these laboratories, some of which is being moved from its original location to newer and more suitable quarters, will be put in the best possible condition for efficient operation.

Some of the problems now receiving attention are very important ones. Among these may be mentioned the calibration of testing machines, for which there is a constant demand from the owners of such machines in this country, and the testing of aircraft materials.

The Emery hydraulic testing machines will be moved to the new quarters as soon as practicable. This will interrupt the work somewhat during the coming year. The investigation of the strength of aircraft parts for the Navy, which will require several months to complete, should be finished before this equipment is dismantled. By that time it is believed that everything will be ready in the new location. The use of a room adjacent to the middle wing of the industrial building, having excellent light, will be very beneficial. All the laboratories of this section will then be so grouped that the equipment can be efficiently used and can be given proper supervision. Much still remains to be done before these laboratories are in satisfactory condition, but progress will be made.

Tests of Large H Columns.

The results of the tests of large columns made for the American Society of Civil Engineers showed a systematic difference between the strength of columns made of thin and thick rolled material. The present series of tests were made to study this effect in columns of still larger cross-section. Thirty-nine columns having cross-sections of five different types, (1) light and (2) heavy built-up plate and angle sections, (3) light built-up channel sections, (4) light and (5) heavy solid rolled sections, were tested in the 10,000,000-pound testing machine of the Bureau of Standards at Pittsburgh. The cross-sectional areas were approximately 40 square inches for the light and 85 square inches for the heavy sections, and the lengths were 12, 18, and 24 feet.

Physical tests and chemical analyses were made on coupons cut from the columns and the results compared with those from tests of the complete columns. The following summarizes the results of the tests:

1. The columns were carefully prepared, their ends were accurately surfaced, and they were carefully centered in the testing machine. This is shown by the uniformity of the stress-strain curves and by the steepness and sudden break in the lateral deflection curves.

2. The differences in the observed average column strength of these columns is almost wholly due to differences in the yield point of the material of which they were constructed.

3. Lack of homogeneity of the material may account in part for the low efficiencies of the heavy-rolled sections.

4. Secondary failure did not occur except, possibly, to a slight extent in the channel section. This shows that the webs were amply strong enough to carry the shear and the flanges thick enough to prevent buckling.

5. A small increase in economy in the use of the steel might be obtained by increasing the radius of gyration of the sections.

6. In view of the controlling influence of the yield point of the material upon the column strength, a more precise standard of definition and measurement of yield point is needed.

7. A properly standardized "drop of beam" yield point will furnish a measure of the strength of column material provided the material is sufficiently homogeneous, but a different measure will be obtained from the "useful limit" point or other extensometer measurements.

8. The yield points determined in commercial mill tests apparently bear no relation to the column strength.

9. Heavy-rolled material bought under the same material specifications (American Society for Testing Materials) will show a lower column strength than light-rolled material, because of a lower yield point.

10. Increase in the ultimate strength of steel, due to increased carbon content, apparently does not increase the yield point as greatly as a corresponding increase due to working

Strain-Gauge Measurements on Welded and Riveted Tanks.

To determine the value of welding for sheet-steel pipe lines, instead of the usual riveted construction, four tanks 10 feet long and 4 feet in diameter, made from $\frac{5}{16}$-inch plate, were tested under internal hydraulic pressure. One had riveted, one lapwelded, and two butt-welded seams. The welds were made with electric arc welding machines.

Strain-gauge measurements were made longitudinally, transversely, and diagonally on the cylindrical surface of the tanks, both across seams and on the unjoined plate. Measurements were also taken on the shell adjacent to the ends and also on the end. To determine the effect of the manhole, measurements were made around this opening in the shell on one of the tanks.

Strain-gauge readings were taken for each 50 pounds per square inch increment of pressure, and at 300 pounds per square inch an impact test of the seams was made with a sledge and the readings continued for increments of 100 pounds per square inch until failure occurred. The observed strains were compared with the theoretical strains. Due to the large number of observations it was found convenient to show the experimental results graphically. It was found that the accepted theory for the design of tanks is sufficiently accurate if the stresses are not increased by secondary stresses.

The strains computed by the common theory for thin cylinders agree well with the more exact theory and with the measure of strains, provided the latter are not affected by secondary causes. Due to the fact that the shells of the tanks were not accurately cylindrical, great changes in the strain intensity were caused by secondary stresses.

The tanks fell into two groups. One butt-welded tank and the riveted tank failed at about the same working pressure, 200 pounds per square inch, due probably to poor welding in the case of the welded tank. The other butt-welded and lapwelded tank withstood at least twice this pressure. In all cases the tanks failed by leaking

so rapidly at the seams that it was impossible to maintain the pressure.

Permissible Working Stresses in Steel Buildings.

At the request of the Building Code Committee of the Bureau an investigation of the permissible stresses in steel buildings was undertaken. When the steelwork for the new annex to the Hotel Statler in Buffalo was redesigned a stress of 18,000 was used instead of 16,000 pounds per square inch, as required by the Buffalo building code. Special permission was obtained for this increase in stress. If this was practicable for other buildings, the cost of construction could be reduced. This, in turn, would stimulate building construction and help to relieve the present crisis.

A preliminary survey of the subject indicates that little is to be gained from tests of structural steel as made at present. Steel having a higher strength, perhaps obtained by heat treatment, can be used, but the cost would probably be great, and the inspection and testing would have to be conducted with great care. For buildings subjected only to static loading or, in other words, to a constant load which remains in place for long periods of time, comparatively high stresses can be used. Great care must, however, be exercised to design the building for the loads which will actually occur. If the designed load is greater than the actual load, a condition which often occurs, a waste of material results. If, on the other hand, a greater load is used, costly failures are probable.

A summary of the stresses permitted by the building codes in this country is included in this report, and also references to articles in which different phases of the question are considered. An outline of the investigations which should be made before any change in the present permissible stresses is recommended is included. This whole subject is one which should receive careful consideration, as very important interests are involved. It seems probable that the construction of many types of building could be cheapened without serious disadvantages, but the amount of saving can only be estimated after a thorough survey of the possibilities.

Strain-Gauge Test Under Load of the Arlington Building.

This reinforced concrete building occupied by the Bureau of War Risk Insurance has a floor system of terra-cotta tile and reinforced concrete, upon which few tests have been made. At the request of the Treasury Department portions of the floor system of this building were sand loaded and the resulting deformation of the structure measured with a strain gauge. These data are being prepared for publication. A great deal of work was involved in analyzing the results and preparing the drawings for reproduction.

Investigation of the Strength of Hollow Brick Walls.

To economize in material and so lower the cost of building construction, walls have been designed using the usual size of brick but arranging them so as to leave air spaces in the wall. Walls of this type are being tested under concentric load to determine their strength. They are 6 feet wide, 9 feet high, and both 8 and 12 inches thick. For comparison solid brick walls of the usual con-

struction of the same size are made and tested. As the load in a building is not uniformly distributed over the section of the wall, it is planned to load walls in the future over half their thickness only to approximate actual conditions. Although these tests are not complete, some interesting results have been obtained, and it is believed that information will be secured which will be of considerable interest and value.

Investigation of the Fatigue Resistance of Sheet Metal.

At the request of the Navy Department, and in cooperation with the National Advisory Committee for Aeronautics, the fatigue resistance of sheet metals is being determined. The metals to be used are those suitable for aircraft construction, particularly those having light weight, such as duralumin. The thicknesses will vary from 0.02 to 0.10 inch.

Two testing machines of unique design have been made and found to give satisfactory results upon the thinner sheets. Drawings have been prepared for both the flexural and the impact fatigue machines, and several of each are now being constructed. In addition to the fatigue tests, tensile, bend, and other tests will be made to find the other properties of each material. These fatigue tests are of great importance, as experience seems to show that many of the light alloys, including those containing aluminum, often fail from fatigue. As many of these materials have not been used for a sufficient time to determine their suitability for aircraft construction, laboratory tests are especially important to prevent the use of unsuitable material, with disastrous accidents and possibly great loss of life.

Investigation of the Impact Resistance of Sheet Metal.

At the request of the Air Service of the Army the resistance of sheet metal to impact is being studied. The materials are those suitable for aircraft, and a wide variety of both ferrous and nonferrous alloys are to be included. The ability to absorb a large amount of energy or work may prove to be a very important quality in metals used for aircraft. For materials having equal strengths it is believed that a great difference in impact resistance will be found. As no apparatus suitable for this work was available, an Izod and a Charpy impact machine were modified to test sheet-metal specimens by tensile loading. The results with the Izod machine proved to be consistent, and it will be used for the test program. The materials will all be tested in tension, bending, etc., as well as in impact.

Investigation of Body-Bound Bolts.

An investigation was made of liquid air and an explosive charge for body-bound bolts. The experiments were conducted at the request of the Bureau of Construction and Repair, Navy Department, in order to determine the force required to cause slipping of a body-bound bolt.

Two methods of obtaining a tight fit between a bolt and the material surrounding it were used in an effort to find one which could be used for attaching the lugs of turret guns to the deck. The bolts used for this purpose are subjected to great shearing stresses

when the guns are fired. At the present time the Navy uses taper bolts, which are drawn tightly into taper holes.

The tests were made on bolts which had been body bound by the following methods: (1) Liquid air, shrinking the bolt by immersing in liquid air and allowing it to expand in the hole; (2) explosive, inserting the bolt, which was a loose fit in the hole, and expanding it by an explosive charge placed in a small hole in the axis of the bolt.

Experiments had previously been made on cylindrical pins which were from 0.001 to 0.0015 inch larger than the holes, and which were contracted by immersing in liquid air to fit the holes. Tests were also made on taper pins, which were contracted by immersing in liquid air and then driven into tapered holes.

The results of the investigation on the use of liquid air showed that a tighter fit can be obtained with taper pins than with a cylindrical pin. The average unit frictional resistance as shown by the tests on cylindrical pins was 2,150 pounds per square inch, while the average value for the taper pins was 3,000 pounds per square inch.

The test of the bolts expanded by explosive charges showed that satisfactory results can be obtained by this method. The average unit frictional resistance was 2,180 pounds per square inch. The tightness of the fit is dependent upon the size of the hole bored in the axis of the bolt to contain the powder charge, as well as upon the pressure of the explosion.

Investigation of the Strength of Screw Threads for the National Screw Thread Commission.

The data have been compiled and the report completed on the investigation of the strength of screw threads for the National Screw Thread Commission. In this investigation tests were made to determine the effect on the strength of screw threads produced by different clearances in the pitch diameter of the threads of a bolt and nut assembly. The clearance was varied from 0, or a snug fit, to 0.049 inch. The results showed that for clearances up to a certain value the strength of the screw threads remained about the same, but clearances above 0.03 inch for a ⅜-inch 16-thread assembly very materially reduced the strength of the threads. It was also found, as would be expected, that the greater the number of threads per inch the greater is the decrease in strength caused by any given clearance.

The investigation also covered the effect of variations in the angle that the face of the nut makes with the plane at right angle to the axis of the bolt. This angle was varied from one-half minute to six degrees. The results showed that the strength of the screw threads was not affected by this change.

Streamline Stay Rods.

For the subcommittee on metals of the National Advisory Committee for Aeronautics a specification was prepared for the purchase of these important parts of an airplane structure. The pilots and others connected with the operation of airplanes feel that these streamline rods are unreliable, and that crashes often result from their failure, due possibly to fatigue.

Taking the Bureau of Construction and Repair, Navy Department Specification No. 61, as a basis a very careful and thorough study

was made of all available data and a new specification prepared. A better distribution of sizes was made, so as to obtain more nearly a geometrical series, and the tolerance in sectional area was also graded. The British standard fine screw thread close fit was recommended. All the dimensions and ultimate strengths were recomputed and diagrams made to compare the proposed values with those in the above-mentioned specification.

The material, method of manufacture, protective coating, method of test, and inspection were all carefully considered by the subcommittee and every effort made to prepare a specification which would insure the best streamline rods which could be manufactured at the present time.

It was found impractical to require fatigue, X ray, or magnetic tests at this time, but the use of these tests is urged in the hope that they may prove reliable in eliminating unsuitable material which occasionally gets into service at present.

Investigation of the Failure of a Duralumin Airplane Elevator.

An elevator from a J. L. postal airplane was submitted for test to determine the cause of the disintegration of the duralumin tubes and sheets of which it was made. The elevator, which had only been in service two months, showed brittleness at the trailing edges where portions of the sheets forming the elevator surface had broken away. Tests showed that the brittleness extended for several inches from the edge and occurred where two sheets were in contact. This may be due to electrolytic or to chemical action upon an overworked material, starting near the rivets where high local stresses occur and where moisture may accumulate. The behavior of this material shows that further study and investigations are needed if the light alloys, particularly those containing aluminum, are to be used with safety for aircraft construction.

Calibration of Large Testing Machines.

Calibration of 2,000,000-pound Chain-Testing Machine at the Boston Navy Yard.—A comparison calibration of the 2,000,000-pound chain-testing machine located at the Boston Navy Yard was made by the calibration bar, extensometer method. A large 5¼-inch diameter bar of nickel steel was used for this purpose and the deformation measured by means of a special extensometer. The bar was first loaded in the large Emery machine of the Bureau and the elongation measured for increments of load of 10,000 pounds. Six runs to 1,000,000 pounds were made. The bar and extensometer were taken to the Boston Navy Yard and six loadings to 1,000,000 were made in a similar manner. A comparison of the results obtained from both machines indicated that the chain-testing machine was reading about 3.4 per cent higher than the large Emery machine.

Calibration of a 1,000,000-pound Hydraulic Press.—A comparison calibration of a 1,000,000-pound hydraulic press belonging to this Bureau was made by the calibration bar, extensometer method. A special 4½-inch diameter compression bar 28 inches long was used. Several loadings to 1,000,000 pounds were made both in the large Emery machine and in the hydraulic press and the deformation determined for

increments of loading of 10,000 pounds by means of a special extensometer. From the results a comparison calibration curve was obtained. It was found that the hydraulic press was reading about 4.2 per cent higher than the large Emery machine.

An Investigation of Oxyacetylene Welding and Cutting Blowpipes.

At the request of the War Department the Bureau conducted an investigation of the operation, efficiency, and safety of oxyacetylene welding and cutting torches. Apparatus from 14 of the most prominent manufacturers was tested. All tests were conducted under standardized conditions, the practical work of cutting and welding being carried on by a group of experienced welders and cutters, who were directly under the charge of the Bureau. Every effort was made to secure data that would be representative only of the blowpipe action.

As a result of this investigation it was determined that none of the commercial cutting blowpipes procurable are designed according to any definite theory; that none of the cutting blowpipes are efficient in cutting metal of all thicknesses, and probably that considerable improvement can be made in economy in cutting 2-inch metal and possibly in other thicknesses. The results of the investigation would also indicate that probably the maximum thickness of metal that may be cut economically with oxyacetylene blowpipes is in the neighborhood of 12 inches.

With regard to the welding blowpipes, this investigation proved conclusively that none of the blowpipes submitted for test were correctly designed. As a result of improper design none of the welding blowpipes proved free from flash-back phenomena. Most of them, therefore, are not fundamentally safe pieces of apparatus and, further, the inherent defects in design result in the making of unsound welds. This latter condition has generally been attributed to the operator, and as the result of the frequency with which unsound welds occur the oxyacetylene fusion welding process has been rather severely criticized. It is believed that the results of the investigation show that with a properly designed welding blowpipe satisfactory fusion welds may be made.

Summary of Tests.

The following statement shows various materials tested by this section during the fiscal year ending June 30, 1921, together with the number of specimens of each type:

Metals.

Iron and steel:	
Cast iron	24
Steel	517
	541
Aluminum and aluminum alloys:	
Aluminum alloy	21
Aluminum alloy, duralumin	70
Aluminum alloy, elektron	38
	129

Copper, brass, and bronze:	
Brass	10
Copper	19
	29
Miscellaneous metals and alloys:	
Bearing metal, "ceco"	6
Dental amalgam	6
Dow metal	6
Monel metal	8
	26
Fiber rope and wire rope.	
Rope, manila	155
Rope, wire	21
Scout guard rope	2
Cordage	32
	210
Other materials.	
Hard horn fiber	26
Redmanol	3
	29
Calibration of testing machines.	
Scott type Q	1
Miscellaneous.	
Bars, clay	80
Belting	7
Body bolts	17
Bomb points	4
Bomb lugs	6
Bolts and nuts	37
Cable, current meter	1
Chain, sash	18
Chain, skid	1
Chisel, cold	6
Chisel, track	1
Enamel for sheet iron	18
Gears	7
Glass, port and skylight	30
Grating, reticulated	2
Hooks, tent	10
Keyways for armor plate	6
Seals, Acme	4
Springs, bed	2
Terra cotta	396
Webbing	10
Wire, brass	8
Wire, bronze	8
Wire, magnet	37
Wire, music	60
Reinforced concrete columns	4
	780

Publications.

The following is an enumeration of the publications which were prepared by this section:

Bureau of Standards Circular 101, Physical properties of materials.
An investigation of oxyacetylene welding and cutting blowpipes (R. S. Johnston), in press.
Results of some tests on manila rope (A. H. Stang and R. L. Strickinberg), in press.

MEMORANDUMS.

Memo VII–1–16: Dimensions and tolerances for the cross-sections of streamline stay wires.
Memo VII–1–18A: Streamline wire specifications.
Memo VII–1–19: Impact tests for woods.

OUTSIDE PUBLICATIONS.

Hardness testing of metals (H. L. Whittemore).
Article in "Mechanical engineering," July, 1921.

General Information Furnished.

Many engineering students, as well as engineers, business men, and others from this and foreign countries, were shown through the testing laboratories. Many of them were seeking information on testing equipment, particularly as to the merits of certain type of machines.

Advice has been furnished and recommendations made concerning rope specifications, methods of testing balls and rollers and the results obtained, metal airplane construction, methods of measuring hardness of metals, methods of measuring the impact resistance of metals, methods of determining the fatigue resistance of metals, methods of testing lock nuts, solving mathematical problems, and working pressure of an autoclave.

CEMENT, CONCRETE, STONE, GRAVEL, AND SAND.

General Outline.

This section is concerned with the investigation and testing of cement and allied materials for construction purposes, the development of new methods of testing, improvement of apparatus for testing, the preparation of specifications covering cement and concrete construction, development of new uses for cement products, the distribution of knowledge concerning their use, and the design and fabrication of concrete structures. The Bureau acts as a testing laboratory for a considerable part of the cement used in the Government's construction work as far as its facilities permit.

The work of the section may be classified under two main headings: (1) Investigations or researches, (2) inspection and testing of cement. These necessarily overlap to some extent, as a certain amount of material testing is carried out by those engaged in research, and a considerable amount of investigative work is done in connection with cement inspection and testing. The available funds, however, are about evenly divided between the two classes of work, and it is convenient in many respects to maintain this classification for reference purposes.

The first group is subdivided into several lines of investigative work, as follows: (1) Constitution of Portland cement, (2) plastic magnesia, (3) stucco and plaster, (4) reinforced concrete, (5) durability of concrete in alkali and sea water, (6) building stone, (7) volume changes in concrete, (8) general concrete investigations, (9) fineness, (10) concrete tanks for oil storage.

Not all of these investigations have been actively pursued during the past year owing to lack of funds, but it is hoped that work on the most important of them at least can be continued later.

Under inspection and testing of cement is included the work of sampling, testing, and shipping of the cement purchased by the several departments of the Government. For carrying on this work laboratories are maintained at Washington, D. C.; Northampton and Pittsburgh, Pa.; Denver, Colo.; and San Francisco, Calif. The laboratories in Pennsylvania are engaged only in the testing of cement, and the other branches are equipped to do a limited amount of concrete and miscellaneous testing.

Constitution of Cement.

In order to advance the work with Sorel cement no new work was inaugurated dealing with the constitution of Portland cement. There were placed in press the results of the investigation of the properties of the aluminates high in lime. These at early periods produced strengths much in excess of those produced by Portland cement either on a mortar or concrete. The strengths developed at three years were also very high, though when the aluminates were "commercially free" of silica there was a retrogression in strength between the one and three year period. In those cases when silica had been added the strengths were lower, but showed a continuous increase with age. The presence of calcium sulphoaluminate was noted in a number of the mortar briquettes in large amounts, but in no case had it produced disintegration. It appeared in the voids in the form of a mass of loosely bound acicular crystals. This is the compound supposed to produce disintegration in concrete submitted to the action of sea water. However, in these particular specimens it appears in much greater quantities than ever noted in sea-water concrete, but has not produced any signs of disintegration.

Sorel Cement.

Several lots of magnesite from different localities, after crushing and grinding in different sizes, have been calcined under closely controlled conditions as to temperature and length of time of burning. From the resulting calcine several typical mixtures of both a flooring and a stucco composition have been made. These have been made into the usual laboratory test pieces and in addition have been placed in service in the form of panels of flooring and stucco. The work has not advanced sufficiently far to permit of drawing any final conclusions. However, almost with the first mixtures made there was noted the marked effect which different aggregates produced upon the same calcine. Thus a calcine which produced a large expansion with one mixture of aggregates was satisfactory when the mixture was changed. The lean stucco mixtures are not as sensitive to differences in the properties of the calcined magnesite as are the richer flooring mixtures.

Test of a Concrete and Hollow-Tile Floor Reinforced in Two Directions.

The structure tested (referred to as the Waynesburg slab) is a large slab made up of clay tiles and reinforced concrete ribs. In the Annual Report for 1920, page 189, a description is given of the test

referred to. As stated in that description the loads originally applied did not cause failure of the slab, and in order to obtain further information additional load tests were made in November, 1920. In this test three panels were loaded in the effort to bring about failure and thus to determine the real factor of safety. After the loading material had been piled 22 feet high it seemed unsafe for the workmen to continue operations and the test was discontinued. On account of the fact that the test could not be carried to failure it is not known how great a load could safely be permitted on that slab, but that the test results indicate possibilities for economy in building construction will be evident from the following statement:

Current standards for design would permit as safe live loads on the slab tested 33 pounds per square foot for the 16-foot square panel and 17 pounds per square foot for the 16 by 19 foot 3-inch panel, while the 16 by 22 foot 6-inch panel would not be adjudged quite heavy enough to carry its own weight. The loads actually placed on the panels of three sizes were 1,413, 1,184, and 920 pounds per square foot, respectively. Reduced to equivalent uniform load they are approximately 1,300, 1,090, and 850 pounds per square foot, respectively, and correspond to factors of safety of 16.2, 17, and 18.6 for the three sizes of panel, if the design loads be based on current standards for design. These loads were applied in November, 1920, and nearly eight months later (June 30, 1921) they are still in place and have not caused failure nor excessive increase in deflection.

Moments and Stresses in Slabs.

About a year ago the Bureau undertook in cooperation with the American Concrete Institute a study, by analytical methods and by correlation of test data which had been secured by various agencies during the past 10 years, of the subject of moments and stresses in slabs. This study included "flat slabs"—that is, concrete slabs "having reinforced bars extending in two or more directions and having no beams or girders to carry the loads to the supporting columns"—and reinforced concrete or tile and reinformed concrete slabs supported on girders, such, for example, as the Waynesburg slab. The analysis developed in this study is probably the most complete which has yet been made, and a comparison of the results of the analysis with the stresses developed in the tests studied indicates a fair agreement between the analysis and the tests for loads which cause stresses within the yield point of the reinforcement, but the reserve strength which is developed after the yield point of the reinforcement is reached appears to be much greater for the slabs tested than for the individual units ordinarily tested in laboratories. In most designs no account is taken of the tensile strength of the concrete, but the indication from the tests is that the tensile strength of the concrete is a source of considerable additional strength for reinforced concrete slabs, and possibly also for continuous beam construction. The results of this investigation have formed the basis for the specifications for flat slabs referred to in later paragraphs. These specifications were prepared by a member of the Bureau's staff.

Specifications for Concrete and Reinforced Concrete.

A member of the staff is a member of the joint committee on standard specifications for concrete and reinforced concrete. This joint committee is made up of five representatives from each of the fol-

lowing organizations: American Society of Civil Engineers, American Society for Testing Materials, American Railway Engineering Association, American Concrete Institute, Portland Cement Association.

This joint committee has just made public its first progress report, and through the committee the Bureau has taken an important part in the formulation of the specifications. In the work of preparing these specifications the investigations of the Bureau, previously referred to under the heading of "Test of a hollow tile floor reinforced in two directions" and "Moments and stresses in slabs," have been of much value. The possession of other data has also placed the Bureau in a position to be of assistance to the committee. Among these other data are the results secured by the Bureau from the investigations by the concrete ship section of the Emergency Fleet Corporation and from the technologic branch of the Geological Survey about 1910.

Shearing Strength of Concrete Beams.

Although the results of the shear tests made on concrete beams in connection with the concrete ship investigation (see p. 207 of Annual Report for Year Ending June 30, 1919) have not yet been published, the results obtained have received recognition in the progress report of the joint committee on standard specifications for concrete and reinforced concrete. Lectures presenting the results of these investigations have been given at different places, and much interest has been shown in the results attained.

Durability of Concrete in Alkali and Sea Water.

Owing to reduced appropriations little has been accomplished during the past year. An attempt has been made, however, to keep in touch with the work carried on by other agencies, and laboratory tests have been undertaken by the Chemical Division of the Bureau to determine the efficacy of bituminous coatings as a protection for cement drain tile against alkali attack. The report on the condition of the several experimental installations of drain tile in the West, based on the inspections of 1919 and 1920, has not yet been completed. This report will probably be published as a Technologic Paper, supplementing Technologic Paper No. 95, during the coming year.

Automatic Freezing and Thawing Apparatus.

A new freezing unit has recently been installed in connection with this apparatus, the purpose of which is to enable one to make a large number of freezings and thawings with minimum loss of time. Instead of determining the effect of a small number of freezings on the strength and appearance of a material, as the test is usually made, the procedure is to determine the number of freezings which produce complete disintegration. This is believed to be a more definite means of comparing the weather-resisting properties of materials. A large amount of work is planned in connection with this investigation, including tests on building stones, stucco, terra cotta, slate, and the effect of waterproofing materials in preventing disintegration.

Discoloration Tests on Indiana Limestone.

The problem of determining and eliminating the cause of stains on masonry of this important material was undertaken more than a year ago. Twelve panels of the limestone were erected on the

industrial building in September, 1919. These panels were set up in mortars of various cements, using different combinations and methods of waterproofing. These tests were of value in a general way, as they served to indicate the source of the trouble, but it was soon learned that more severe conditions were necessary in order to produce definite results. The study of the panels and of limestone buildings indicates that it is only in the parts of the structure where a large amount of water penetrates the stone and leaches through the mortar joints that the stains occur in appreciable amounts. Hence, in order to determine more definitely the effect of different cements, tests were made which gave exaggerated conditions. Water was made to leach continuously through the mortars and limestones for a considerable length of time. Tests of this kind indicate that some cements produce a much more marked stain than others, but that the stains will not always occur with the same cement. White cements and lime mortars also produce stains, but usually less intense than normal Portland. The indications are that the stain in question—that is, the brown discoloration frequently called "iron stain"— is due to a small amount of organic impurity in the limestone. Water in leaching through the mortar appears to become a solvent for this organic matter, which is carried to the surface, where it is deposited as the solvent evaporates. The organic impurity in the limestone varies, and hence stains may occur in one part of the structure while another part subject to the same conditions may remain free from stains. Waterproof materials are being experimented with as a means of preventing the leaching of water through the mortar and limestone. So far no cement has been found that will not produce stains on the limestone when a large amount of water leaches through.

Colorless Waterproofing Materials.

An extensive series of tests is in progress on colorless waterproofing materials applied to natural stone. These tests include exposure tests to determine the durability and effectiveness of the coatings to prevent the absorption of water; freezing tests to determine the value of the materials in preventing frost action; and carbonic-acid tests to determine the effect of carbonic atmospheres on treated specimens. A preliminary report is being prepared giving the results of exposure tests for a period of six months.

Investigations of Slate.

Samples of slate from various quarries are being collected, and tests are in progress to determine the physical properties of the various materials. Special attention will be given to the effect of ribbons on the strength and other properties of the slate.

General Tests on Concrete Floor Treatments.

The sections of concrete floor in the corridors of one of the Bureau's buildings which were treated with various concrete floor treatments have now been in service three years. These have been studied with a view to determining the relative value of the various treatments. Four distinct types have given good service with very slight signs of wear during this period. Some of these are non-proprietary and are very inexpensive. A report is available which

describes the nature of the materials under test, the methods of application, and the results of observations on the treated panels after two years of service.

Volume Changes in Mortars and Concretes.

This work has been discontinued except for continuation of the measurements on mortar slabs made up last year. The first phase of the investigation—that is, its bearing on the durability of stuccos—was practically completed and very valuable information was obtained. It was shown that the amount of shrinkage in mortar coats was largely dependent upon the amount of water retained in the mortar when set occurred, and that the elimination of the excess water resulted in a marked reduction in the shrinkage. The removal of excess water can be brought about by control of the "suction" or absorption of the undercoats, which thus becomes an important factor in good stucco work.

Air Analyzer.

This apparatus was developed at the Bureau some years ago in connection with the study of the effect of fineness of Portland cement and has been found applicable to fineness determinations of other materials. During the past year a considerable amount of effort has been devoted to modification of the apparatus in such a way as to adapt it to making finer separations and also to enable it to handle softer materials. By reverting to the old principle of blowing air upward through the sample of material under examination and accurately controlling the velocity of the air by using a flow meter of the type described in the Bureau's Technologic Paper No. 183 successful fineness determinations have been made on such materials as ochre, hydrated lime, plaster of paris, etc. Moreover, the size of separation has been reduced to approximately 10 microns; that is, the diameter of the largest particles removed by the smallest air current is about 0.01 millimeter, or about one-tenth of the diameter of the largest particles passing a No. 200 sieve. It is thus possible to obtain a better idea of the fineness of powders which have heretofore been analyzed by less accurate sedimentation methods.

Standard Cement Sieves.

During the year 173 No. 200 cement sieves were standardized as compared with 56 standardized in the fiscal year 1920 and 56 in 1919. This is an increase of over 200 per cent. It is believed that at the present time no difficulty should be experienced in obtaining No. 200 sieves meeting the standard specifications.

U. S. Standard Sieve Series.

As noted in the Annual Report for 1920, specifications for a new series of standard testing sieves have been developed in cooperation with the Weights and Measures Division of the Bureau. In connection with the standardization of these sieves the present specifications are based only upon average measurements of openings and wire diameters, with certain tolerances upon these averages and upon the maximum openings. It is recognized, however, that appreciable differences in sieving values of sieves meeting these specifications

will exist, particularly in the finer sieves, and data will be obtained as the new sieves come into general use as to the magnitude of these differences in sieving values and the need of correction factors to be applied whenever results of the highest accuracy are required. At the present time correction factors are determined only for No. 200 sieves that are submitted for standardization, the standard cement fineness sample being used for this purpose. It is planned eventually to prepare standard samples whereby correction factors may be determined for sieves finer and coarser than the No. 200 in the U. S. standard sieve series.

Sieves may now be obtained from two manufacturers that are made according to the U. S. standard sieve series and a third manufactures a series of testing sieves of which the majority nominally conform to these specifications.

Standard Samples.

The Bureau prepares and keeps on hand for issue standard fineness samples of cement for checking up No. 200 sieves. They are supplied in two degrees of fineness and are issued in sealed glass jars, each jar containing about 160 grams, enough for three 50-gram sieve tests. Each sample is accompanied by full directions for its use. A nominal price of 50 cents, sufficient only to cover the cost of preparation, is charged for each sample. With these samples No. 200 sieves may be compared with the Bureau's standards and correction factors obtained. These samples are also used by the Bureau in checking up its own sieves and in the standardization of No. 200 sieves submitted for certification. The two samples on hand at present are 46g–78 per cent passing the No. 200 sieve and 47c–89 per cent passing the No. 200 sieve.

Concrete Tanks for Oil Storage.

This investigation was undertaken in 1918 at the request of the Navy Department and the Emergency Fleet Corporation, and has since been continued as an industrial problem. The work has been devoted largely to determining the seepage losses which occur in well-fabricated concrete tanks of 1:1½:3 mixtures filled with mineral oils, covering practically the entire range of fuel oils from light gasoline to heavy road oil. This portion of the investigation has been practically completed and a report has been prepared for later publication giving the results both of laboratory work and extensive field inspections. Taking into account the nature of the test tanks and the conditions under which they were made in relation to the conditions obtaining in actual field construction, the general conclusion has been reached that well-built concrete tanks are suitable for the storage of fuel oils up to about 35 or 40° Beaumé, and that the losses of such oils by seepage should be practically negligible. On the other hand, the investigation indicates that the use of concrete tanks for storage of kerosenes and gasolines is hardly warranted except under special conditions, and that tanks which are designed and built for this purpose should be thoroughly tested for permeability before being put into service.

A considerable amount of work has also been done on the testing of so-called oil-proof coatings and treatments. In general, it has

been found that none of the treatments tested are sufficiently effective to warrant recommendation of their use. Tin foil applied over the interior surface of the tanks with spar varnish is the only treatment which promises to reduce the losses of the lighter oils to negligible quantities. Data have also been obtained on the effect of pressure on rate of seepage, on the relation of viscosity to rate of seepage, and on the tightness of joints between sections of concrete placed at different times.

Measuring the Consistency of Concrete.

Further comparisons have been made between the slump and flow table methods of measuring consistency of freshly mixed concrete. The general conclusions from these comparisons may be summarized as follows:

For measuring the consistency of rich or easily workable mixtures both methods are satisfactory and give results which are in close agreement. In the case of leaner and harsher mixtures, the slump test does not function properly until the consistency is relatively wet, and then only over a narrow range. On the other hand, the flow table gives consistent readings on mixtures of all proportions throughout the workable range. It has also been found that the variation in making repeated consistency measurements on any given batch of concrete is less with the flow table than with the slump test. The chief objection to the flow table at the present time is that it needs standardization in order that results obtained in different laboratories may be directly comparable. As this standardization requires only a general agreement among testing engineers as to the design of the flow table without necessitating extensive investigations as to the effects of various factors, it is to be hoped that the American Society for Testing Materials will soon take steps to prescribe uniform dimensions for this very useful piece of laboratory equipment.

Measuring the Time of Set of Concrete.

The flow table has been found useful in determining the time of set of a concrete mixture. From the time when mixing is completed a batch of concrete gradually loses plasticity, or flowability, a property which the flow table is designed to measure. The time of set occurs when the concrete changes from a plastic to a rigid body; that is, when the point of zero flow is reached. By molding a series of test specimens and determining their flow at intervals after molding the time elapsed between mixing and the point of zero flow can be determined. In the testing of neat cement it has been found that this method gives close agreement with the Vicat needle method for the time of initial set. In practical applications the method has been found useful in determining the effect of various admixtures on the time of set of concrete—e. g., hydrated lime and calcium chloride—and serves to indicate the length of time during which a concrete mixture retains a sufficient degree of flowability for proper placing. Detailed results of this investigation were presented in a paper before the American Society for Testing Materials in June, 1921.

Tests of Concrete Used in Georgetown Bridge.

Concrete is the principal building material used in the construction of the new arch bridge across the Potomac River to replace the old Aqueduct Bridge at Georgetown. The concrete laboratory of the Bureau has been cooperating with the officers of the United States Engineer Corps in charge of the work, and samples of the concrete obtained at the time that the various sections of the bridge were being poured were tested. During the year over 500 concrete test cylinders, 6 by 12 inches in size, were tested in compression, these specimens being taken during 125 days of concrete pouring. In addition to this work samples of cement, sand, and gravel used in making the concrete were tested from time to time.

Concrete Accelerators.

Tests of concrete accelerators have been continued during the year. In the latter part of the year a series of tests on the calcium chloride type of accelerators was being carried out in cooperation with the American Society for Testing Materials. In this series opportunity was taken to acquire additional information on hand mixing *v.* machine mixing in the testing of concrete and also upon the relative uniformity to be obtained from mortar test pieces in the form of cubes, cylinders, and prisms. In general it may be stated that the calcium chloride type of accelerator apparently has a beneficial effect on most Portland cements, not only in increasing the early rate of hardening but also in tending to correct such faults as quick setting and unsoundness. A limited number of experiments were made to determine the effectiveness of calcium chloride in cold-weather concreting, but inability to control or predict weather conditions led to the postponement of further tests along this line until a refrigerating system was available in which the desired temperatures could be maintained. It is possible that this work may be resumed during the coming year.

Slag as Concrete Aggregate.

A blast-furnace slag from banks in Virginia was tested as a concrete aggregate in comparison with local gravel. The strength results confirmed previous tests of the Bureau that blast-furnace slag as a coarse aggregate is capable of producing just as strong concrete as gravel, the conditions of the tests being the same.

The bulletin issued last year by the Bureau on Blast Furnace Slag as Concrete Aggregate is being revised and the new issue will contain general information on production, tests, and specifications, together with a short bibliography on the subject.

Investigation of a Special Cement.

Throughout the year work has been progressing on a Portland cement treated by a special process of English origin, for which unusual claims were made in regard to waterproofing and oil-proofing properties. The product was also stated to have greater strength than the normal Portland cement. As the principle involved in this process had long been known and recognized by cement chemists, the Bureau felt justified in undertaking a limited investigation of the material, and a more extensive program was made possible by the interest of a Canadian company, who supplied a research associate

for this problem during a period of 11 months. In view of general interest in the use of concrete tanks for oil storage and in view of the claims made for the treated cement, particularly as to its suitability for the construction of "petrol" reservoirs, the Bureau's work was largely devoted to a study of the permeability of concrete made with the special cement in comparison with that made with normal—that is, untreated—cement from the same source. The work of this investigation is approaching completion, and a final report will be rendered early in the coming fiscal year. It is evident, however, that the claims for the product in regard to impermeability will not be borne out by the tests. Just what degree of merit the product may be entitled to can not be decided until the results of all the tests are available.

Miscellaneous Tests.

The usual number of tests of concrete aggregates and miscellaneous materials have been made during the year. Most of these were submitted by Federal Government agencies in various parts of the country, a considerable number were submitted by State governments and State highway departments, and a few were submitted by manufacturers or private concerns. Including the work of the Denver and San Francisco laboratories, the materials tested were concrete aggregates from many sources, building stones, slates, alkali salts, soils and waters, various materials for fineness determinations, defective concretes, copper ore waste, slags, accelerators, floor hardeners, waterproofing compounds, reinforcing steel, galvanized sheet metals, adulterants in lye, gasoline, boiler waters, and paints.

Testing of Cement for Government Purposes.

The quantity of certified cement shipped to Government projects was smaller than in the preceding year. However, there is shown in the table below an increase in rate at the end of the fiscal year, and it is not expected that the next fiscal year will show any further marked decrease in the demands. The cement was used for river development, irrigation projects, bridges, District of Columbia parks, public buildings, naval bases, Army camps, depots and fortifications, Panama Canal, hospitals, arsenals, explosive plants, and island possessions. Among the offices served were Army, Navy, Reclamation, Shipping Board, Indian Affairs, and Public Buildings and Grounds.

Month.	Shipment of tested cement (barrels).		
	1918–19	1919–20	1920–21
July	1,121,960	144,421	99,849
August	1,053,167	168,141	63,625
September	1,053,998	138,164	52,460
October	948,937	133,462	93,532
November	719,711	118,648	75,305
December	247,137	80,939	59,389
January	186,806	79,894	24,880
February	182,265	66,285	29,605
March	311,210	70,835	57,515
April	280,229	79,590	54,054
May	255,646	53,798	59,129
June	227,857	56,605	89,698
Total	6,588,923	1,190,782	759,051
Excluding Panama Canal	6,403,923	1,044,032	724,051
Rejections	742,600	125,919	86,652

Inspection was made at more than 50 shipping points located in the District of Columbia and the following States: California, Colorado, Indiana, Kansas, Kentucky, Maryland, Missouri, Montana, Nebraska, New Jersey, New York, Ohio, Oklahoma, Oregon, Pennsylvania, Texas, Utah, Virginia, Washington, and West Virginia.

In the gradual return to prewar conditions the Bureau's cement-inspection service was withdrawn early in the fiscal year from mills in the Dallas, Birmingham, St. Louis, Louisville, Chicago, and Hudson districts. Inspection was also discontinued at one mill in the Washington (D. C.) territory. Some large Government orders were subsequently placed at mills thus eliminated.

The Bureau's cement-inspection service frequently involves much special sampling, investigating, and testing not included in the regular routine of cement testing. Thus, numerous samples were received for comparative tests, others for referee tests where quality was in dispute, and samples of four cements from foreign countries were submitted for determination of their properties. The importance of testing cement prior to use has been emphasized in numerous instances. In one case the samples submitted were found to have extremely low tensile strength, in another the wholly unsatisfactory quality of cement proposed for use in the construction of concrete boats was established, and in still another case cement obtained through the salvage board and shipped across country for use in constructing bridge piers was found to be finely ground silica sand. One other feature of special service is worthy of mention, and that is the assistance rendered a number of American cement manufacturers in having their product approved for the South American market. The labor involved in the process of obtaining the required certificates to accompany the special reports on a lot of test shipments is quite as great as the labor of testing and making the shipments. It is, however, a service that only the Bureau can render, and one which it should render whenever such service is required.

Foreign Cement Specifications.

A large number of replies were received to inquiries regarding cement specifications made through the various consular agents in other countries. The chief requirements of these specifications have been briefly summarized in a chart, which will soon be available for distribution in printed form. In addition these specifications have been more fully set forth in a larger report. In the latter are described many of the details of the methods used by the different countries in making the various tests. The larger compilation should be of interest to laboratories, not as setting forth procedure to be followed by them, but because it describes and illustrates many of the methods and devices and offers some possible ground for suggestions tending to improve present methods.

Publications Relating to Cement and Concrete.

Publications by the staff of the cement section include the following, which have appeared during the year:

Technologic Paper No. 173, Tests of bond resistance between concrete and steel (W. A. Slater, F. E. Richart, and G. G. Scofield).

Technologic Paper No. 174, Effects of cal as an accelerator of the hardening of Portland cement mixtures (Roy N. Young).

Technologic Paper No. 175, Pouring and pressure tests of concrete (W. A. Slater and A. T. Goldbeck).
Technologic Paper No. 182, Effect of repeated reversals of stress on double-reinforced concrete beams (W. A. Slater, G. A. Smith, and H. P. Mueller).
Report of service tests on concrete floor treatments (D. W. Kessler), mimeographed circular issued by the Bureau in October, 1920.
Moments and stresses in slabs (H. M. Westergaard and W. A. Slater), Proceedings Am. Concrete Inst.; 1921 .
Further tests of concrete tanks for oil storage (G. A. Smith), Proceedings Am. Concrete Inst.; 1921.
Shrinkage of Portland cement mortars and its importance in stucco construction (J. C. Pearson), Proceedings Am. Concrete Inst.; 1921.
Effect of age of test pieces in soundness tests of Portland cement (J. R. Dwyer), Concrete, December, 1920.
Relation between tensile and compressive strengths of cement mortars (J. R. Dwyer), Concrete, June, 1921.
Time of set of concrete (Watson Davis), Proceedings Am. Soc. for Test. Mat.; 1921.
Plastic magnesia cements (P. H. Bates and R. N. Young), Jour. Am. Ceramic Soc.; 1921.

LIME, GYPSUM, AND SAND-LIME BRICK.

General.

The work of this section has to do with the development of standards for these materials, the improvement of manufacturing processes to produce better or cheaper materials, and the collection and dissemination of knowledge which will lead to their more efficient use. The work has been devoted largely to the development of new testing methods and the obtaining of test data for use in the preparation of standard specifications. It has been the custom for a representative of this section to visit manufacturing plants occasionally in order to keep in touch with developments in the industries. During this year 23 lime plants and 1 gypsum plant in Pennsylvania, Virginia, and North Carolina were visited.

Hydrated Lime in Concrete.

Much experimental work has been done to determine what effect the addition of hydrated lime has on the properties of concrete. Previous results have been criticized because it was believed that all concretes should be brought to the same degree of workability before their other properties could be compared and no method of measuring workability seemed satisfactory. A machine for measuring plasticity has been built, and experimental trials indicate that it will give the expected results. The measurement of this property, together with the measurement of consistency by means of the flow table, should give an indication of the workability. Preliminary experiments have been completed by this section and plans have been laid to obtain field data on the same subject in connection with the building of a concrete road by the Bureau of Public Roads.

Panel Tests of Lime Plaster.

Publication of the Bureau's report on the cause of popping of lime plaster has led to a great deal of discussion. As a result arrangements have been made to conduct further experiments on a semifield scale. This work will be conducted under the joint supervision of the Bureau, the National Association of Plastering Contractors, the International Plasterers' Union, and the National Lime

Association. It will consist in the erection and plastering of full-sized partitions at the Bureau under carefully controlled conditions.

Measurement of Plasticity.

The instrument designed by this Bureau to measure the plasticity of hydrated lime has received the official sanction of the National Lime Association. After examining nearly all the brands of hydrate on the market it was decided that a plasticity figure of 200, as determined by this machine, is the limiting figure for a finishing hydrate; that is, a hydrate having a plasticity of 200 or more can be used for the finish coat of plaster. This requirement has been inserted in the tentative specification for finishing hydrate of the American Society for Testing Materials. Arrangements have been concluded whereby plasticimeters are being manufactured for sale.

Quick Setting of Lime Plaster.

One of the points of difference between a lime plaster and other plasters is that the lime sets slowly. In general, it can not be stated that this is either an advantage or a disadvantage, but under special conditions it is sometimes desirable to be able to make lime plaster set quickly. The first step was to devise a means of measuring the time of set of lime plaster. This required some months of experimental work, but a satisfactory means of making this measurement is now available. The problem is now to find some way to treat the lime or something to add to the lime in order that its time of set may be controlled.

Normal Consistency of Sanded Gypsum Plasters.

In the tentative specifications for gypsum plasters issued by the American Society for Testing Materials it was stated that when testing both neat and sanded plasters they should be mixed with enough water to produce a paste of a definite consistency. Since sanded material is used at a drier consistency than neat material, it was felt that this method of testing was wrong. The Bureau was asked to designate a standard consistency for sanded plasters. This work has been completed and the results adopted.

Effect of Fineness on Other Properties of Calcined Gypsum.

Every specification for calcined gypsum contains some requirement as to the fineness of the material. These requirements have been based, as a rule, upon what the trade is accustomed to produce rather than upon the actual needs of the consumer. The Bureau therefore planned to obtain data which would form a fair and reasonable basis for the fineness requirements. This work has been completed and published.

Plastic Gypsum.

Calcined gypsum is not sufficiently plastic to be entirely satisfactory as a plastering material. Other substances are added to it in order to make it spread better under the trowel and to carry more sand. The use of these other substances is justified by the saving in labor and material without impairing the quality of the finished product. Obviously, a still greater saving could be effected if the

gypsum itself could be so manufactured as to have the desired property without the addition of any foreign material. An investigation into this matter has been productive of the desired results. By a slight and inexpensive change in the process of manufacture the plasticity of gypsum can be increased so that it will spread easily and carry a large amount of sand. A patent on the process of manufacture and on the product, "plastic gypsum," has been applied for and dedicated to the free use of the public. Many companies are installing the equipment necessary to make this material, and one has already put it on the market.

Action of Retarders on Gypsum.

Pure calcined gypsum when mixed with water will set in 5 or 10 minutes. This is too rapid for most work; it does not give time to mold the material into the desired form. A retarder is therefore added, which delays the setting to from one-half to six hours, depending upon the purpose for which the material is to be used. "Commercial retarder," which is universally used, is a slaughterhouse by-product of indefinite composition. From the standpoint of the user of the gypsum this retarder may be criticized on several grounds: Since it is of an indefinite composition, its action can hardly be expected to be uniform at all times; it is rather expensive, and a cheaper material might be found; it slows down the rate of set, instead of delaying the beginning of set, and in some cases the latter effect is desirable; it seems to prevent the hydration of some of the calcined gypsum, thereby causing a slight reduction in strength. To answer these criticisms an effort has been made to discover a new material which may be used as a retarder. To date this effort has not been successful, although all of the criticisms have been met except the one of cost.

Adhesion Between Gypsum and Cement.

How to make gypsum plaster adhere to a concrete wall is a question which has puzzled many building contractors. Experience has taught them how to overcome the difficulty, but they are still in the dark as to why certain precautions are necessary. Another phase of the same problem is the use of gypsum mortar pointed with cement for exterior masonry walls. To throw more light on these questions, a study is being made of the chemical reaction between gypsum and cement and of the differential expansion of concrete and gypsum plaster.

Effect of Temperature of Calcination on the Properties of Calcined Gypsum.

The most important step in the manufacture of a gypsum plaster is the calcination of the gypsum. The effect of the temperature of calcination on the chemical composition of the product is well established, but little is known about its effect on the physical properties. Moreover, the presence of impurities may be expected to modify the effect produced by any given temperature. The question is being investigated by calcining natural gypsum rocks at different temperatures and measuring the chemical and physical properties of the resultant products.

Acoustics of Wall Plasters.

This research was started last year by this section and the sound section of the Engineering Physics Division. During this fiscal year the status of the work was such that only the latter section could carry on the work.

Colored Plaster.

A new method for making colored plaster was described in the last Annual Report. It consists briefly in introducing dyed wood fiber into the finish coat of plaster and exposing the fiber by suitable treatment of the surface. The Bureau's publication on this subject has attracted considerable attention, which was further augmented by an exhibit of samples in the booth of the National Lime Association at the own your home show in New York. Progress is delayed temporarily by the inability to connect with anyone who will manufacture the dyed fiber on a commercial scale.

Measurement of the Color of Plaster.

Because of a rapidly growing demand from architects that wall plaster should not be white, but should rather be of such a color as will fit in with the architectural scheme, a means of specifying the color of a plaster is rapidly changing from academic to economic importance. A method for measuring the color of an opaque material had already been developed by the Optics Division of this Bureau, and the adaptation of this method to make it applicable to wall plasters offered little difficulty. While the method of making the measurement is rather cumbersome, the results constitute a decided step in advance. It is now possible to specify the color of a plaster in terms which are definite, clear, and unambiguous.

Specifications for Plastering Sand.

Sand is the major ingredient in all plasters. It seems logical, therefore, that if specifications for the minor ingredients, such as lime or gypsum, are economically justified, surely there should be a specification for sand. On the other hand, sand is a cheap material, which is found locally almost everywhere. It is generally better economy to use a local sand, even of known inferiority, rather than pay the freight to bring in better material. However, experienced plasterers are able to recognize good and poor sands. This knowledge has never been definitely expressed in writing, yet the Bureau feels that it should be made available to the general public. Fifty-three sands from widely scattered localities have been received for investigation. Besides the sieving analyses, the plasticities and tensile strengths of mortars made of these sands and lime, gypsum, or cement have been measured. Other physical properties of these mortars are now being studied.

Effect of the Grading of Sand on the Properties of Sand-Lime Brick.

An investigation conducted by this Bureau some years ago showed that a brick of maximum compressive strength can be made of a mixture of coarse and fine sands in definite proportions. The standard specifications for building brick include requirements for transverse strength and absorption, as well as for compressive strength. It therefore became desirable to know what effect the grading of sand

would have on these two properties. Briefly, the results indicate that the finer the sand the higher the transverse strength and the higher the absorption.

Lime-Water-Glass Paint.

From tests made by the Chemistry Division of this Bureau it seems possible to develop a good paint by the proper application of whitewash and water glass. This matter has been taken up with the National Lime Association and one of the manufacturers of water glass. Some experimental work has been done, but the Bureau has not as yet taken an active part in it.

Tests.

Three of the tests conducted during the year were in the nature of research work, but were made at the request and largely at the expense of private individuals. They were undertaken because they gave the Bureau collateral information, which, however, was not of sufficient scope to warrant separate publication. These three tests were: The measurement of the contraction and expansion of a gypsum block partition, the utilization of waste plaster molds from the terra-cotta industry, and the measurement of plasticities of magnesite stuccoes and flooring compositions.

During the fiscal year this section has made routine tests on 17 samples of lime and 5 samples of gypsum for other branches of the Government, and on 79 samples of lime, 21 samples of gypsum, and 10 samples of sand-lime brick for private individuals.

Cooperation.

This section has cooperated with the brick, lime, and gypsum committees of the American Society for Testing Materials. Each of these committees have prepared one or more specifications during the past year. The specifications for materials used in plastering have been formulated by the Bureau of Standards plastering conference, a body composed of representatives of national associations interested in wall plastering, organized by the Bureau in January, 1920. Tentative specifications for lime used in the manufacture of glass, caustic soda, sulphide pulp, and leather have been prepared by the interdepartmental conference on chemical lime. This body is composed of representatives from the various Government departments. Very active cooperation is maintained with the National Lime Association and the Gypsum Industries Association, both of which maintain fellowships at this Bureau. The Sand-Lime Brick Association, through its standing committee on standards, is in close touch with this section of the Bureau.

Publications.

During the past year the following papers, emanating from this section, have been published by the Bureau:

Technologic Paper No. 169, The measurement of plasticity of mortars and plasters (W. E. Emley).
Technologic Paper No. 181, Colored wall plaster (W. E. Emley and C. F. Faxon).
Circular No. 106—Lime: Definitions and specifications.
Circular No. 108—Gypsum: Definitions and specifications.
Circular No. 109.—Sand-lime brick: Definitions and specifications.

The following papers were published in the technical press, as noted:

Effect of the duration of hardening on the properties of sand-lime brick (W. E. Emley and W. M. Cleare), Proceedings Sand-Lime Brick Association, 1920, p. 17.

How brick piers fail (W. E. Emley and W. M. Cleare), Proceedings Sand-Lime Brick Association, 1920, p. 57.

Durability of sand-lime brick (W. M. Cleare), Proceedings Sand-Lime Brick Association, 1920, p. 37.

Use of lime in construction (W. E. Emley), Rock Products and Building Materials, July 3, 1920, p. 65.

The popping of lime plaster (W. E. Emley and C. H. Bacon), Jour. Amer. Ceramic Soc., November, 1920.

Results of testing gypsum products (W. E. Emley and C. F. Faxon), Jour. Amer. Ceramic Soc., December, 1920.

Normal consistency of sanded gypsum plaster (W. E. Emley and C. F. Faxon), Jour. Amer. Ceramic Soc., February, 1921.

Effect of fineness on other properties of calcined gypsum (W. E. Emley and F. C. Welch), Jour. Amer. Ceramic Soc., April, 1921.

Plastic gypsum plaster (W. E. Emley), Chem. and Met. Eng., April 27, 1921; Rock products and building materials, May 14, 1921; Engineering News-Record, June 16, 1921.

Specifications for color of gypsum plaster (W. E. Emley and C. F. Faxon), Chem. and Met. Eng., June 15, 1921.

RUBBER.

The greater part of the Bureau's work in rubber during the past year has been devoted to the development of standard specifications for materials purchased by the various Government departments. This has involved a large amount of experimental work and a great many routine tests and analyses. The results obtained have also served the purpose of perfecting the Bureau's methods of procedure in conducting physical and chemical tests.

New Equipment.

There was installed during the past year a new vulcanizing press equipped with automatic time and temperature control apparatus which regulates the temperature within 1° F. An automatic pump was installed for the operation of the vulcanizing presses. The Bureau's experimental rubber laboratory is now equipped with all the necessary machinery for compounding and vulcanizing in connection with research work on the properties of rubber and compounding ingredients.

Rubber Tubing.

Commercial rubber tubing used at the Bureau was not giving satisfactory service, and for this reason a number of different types of experimental tubing were made in the rubber section and placed in service in the various laboratories of the Bureau with a view to developing specifications for such material.

Rubber Jar Rings for Canning.

The Bureau has continued its investigation of jar rings in cooperation with the States Relations Service, Department of Agriculture. The object of this work is to determine the aging qualities of jar rings in use or in storage and to revise the existing specification by the inclusion of an accelerated aging test.

Power Losses in Automobile Tires.

The Bureau has undertaken a general investigation of automobile tires and inner tubes, and in connection with this work a rather comprehensive program has been laid out for dynamometer tests to study, among other things, the power losses or energy dissipated into heat in various sizes of cord and fabric tires, operated under different conditions of axle load, inflation pressure, speed, temperature, and tractive effort. Preliminary tests have been made to determine the influence of these factors which, aside from matters of design, are the principal items affecting the power loss in a tire. A continuation of the work will involve problems of design and construction, the influence of "oversize" tires, and of cord tires on power losses, mileage, and general efficiency of operation. An investigation will be made of inflation pressures as affecting the efficiency and economy of tire operation. Tests will be made to determine the effects of tire fillers, shields, puncture-proof tubes, etc., and the properties of cushion tires will be studied.

The dynamometers employed for this work, although designed primarily for investigational purposes, are adapted for routine testing to determine the relative durability of tires and inner tubes. It has been suggested that a number of detailed requirements in the existing Government specifications be eliminated and that a laboratory service test be substituted therefor. In working out a plan such as this the results of dynamometer tests will be of great value in designing a standard tire-testing machine and in interpreting the results intelligently.

The Effects of Compounding Ingredients on Properties of Rubber.

The Bureau has planned an extensive investigation of the properties of rubber and the effect of compounding ingredients on the life of the rubber under various conditions of use and storage. A study is being made of the properties of rubber and composition soles after accelerated and normal aging.

Rubber Analysis.

An important part of the Bureau's work is the analysis of rubber goods purchased by the various Government departments. The long list of ingredients mixed with rubber is constantly being extended. The properties of some of these ingredients are such that the usual methods of analysis give incorrect results; thus the existing methods must be frequently added to or revised.

The mineral fillers in vulcanized rubber are usually determined by ignition. This involves the loss of some constituents and changes in the composition of others. By the use of suitable organic solvents it is possible to remove the rubber and leave behind all the mineral matter practically unchanged. This problem has been studied at intervals during the past few years. Cymene has been found to give very good results. In addition, the Bureau's general analytical procedure was modified in many minor details, so as to save time without loss of accuracy.

Miscellaneous Materials.

Under this heading are included not only a large number of rubber articles, such as hose of various kinds, belting, valves, packings, rubber-covered wire, jar rings, rubber bands, etc., but also many

materials other than rubber. As typical examples of the latter may be mentioned asbestos gaskets, canvas belting, linoleum, flax shot lines used by the Coast Guard, sash cords, hack-saw blades, shoe laces, etc. Special equipment has been developed for testing some of these materials, and in such cases similar tests are made for manufacturers upon request. The usual tests of miscellaneous materials were made for the General Supply Committee, the results being used as a basis for the award of contracts covering the fiscal year 1921–22. Those Government offices which purchase on their own specifications rather than from the General Supply Schedule utilize the Bureau's laboratories to a large extent.

Cooperation with the Rubber Industry.

It is the Bureau's policy to cooperate to the fullest extent with manufacturers, with the view of having the requirements of specifications conform in every way to the best manufacturing practice. When all available sources of information have been utilized, a specification is prepared in tentative form and presented for discussion and final adoption at a conference of the United States interdepartmental committee on specification standardization. In this way the requirements of a specification when approved are such as to insure a commercial product of satisfactory quality and well adapted to meet the conditions of service imposed by the Government.

The following examples illustrate the service rendered the various Government offices by the Bureau acting in an advisory capacity:

The office of the Register of the Treasury reported difficulty in the operation of canceling machines, resulting from the improper functioning of certain rubber rolls. The difficulty was overcome by having a number of rolls possessing the necessary properties made in the Bureau's experimental laboratory. The Bureau made a great many tests and analyses for the Chemical Warfare Service in connection with rubber gas-mask materials. The Bureau cooperated with the Air Service of the War Department in perfecting the various requirements for miscellaneous rubber goods. Service was rendered the United States Shipping Board in the preparation of specifications for rubber hose and packings. The Bureau has been requested to make periodical tests and analyses of samples furnished by contractors on these specifications.

Specifications.

Automobile Tires and Inner Tubes.—The Bureau has been making a study of automobile tires and inner tubes for the past few years. As a result of this work specifications were prepared by this Bureau and are now being used by the War Department, Navy Department, General Supply Committee, Post Office Department, Interior Department, Panama Canal, Treasury Department, and Commissioners of the District of Columbia. These specifications in revised form were recommended for adoption by the United States interdepartmental committee on tire specifications June 8, 1921, and will be published as a Bureau circular. The specifications had been submitted to the Rubber Association of America and to a large number of tire manufacturers, and in their revision careful consideration was given to the recommendations received from these sources.

Fire Hose.—The specification originally drafted by the Bureau has been revised in cooperation with the Rubber Association of America. This standard specification in revised form, as officially approved by the specification committee of the Rubber Association, will be published as a Bureau circular.

Rubber Goods.—At the request of the General Supply Committee, tentative specifications for rubber goods were drawn up by this Bureau. All sources of information, such as investigations made at the Bureau and specifications now in use by other organizations, were utilized in formulating these specifications, a list of which is given below: Cotton rubber-lined fire hose, general specification for rubber goods, rubber bands, air hose, spray hose, steam hose, water hose, rubber stoppers, rubber tubing, molded rubber ice bags, rubber bandages, rubber hot-water bottles, rubber ring cushions, rubber adhesive plaster (zince oxide and plain), rubber dam, rubber sheeting for hospital service, rubber tips for crutches and hospital furniture, rubber rectal tubes, rubber stomach tubes, packing (sheet, plain), packing (cloth-insertion), packing (wire-insertion), rubber valves, rubber jar rings, rubber cement, and radiator hose.

Publications.

Circular 38, "The testing of rubber goods," was revised and amplified; it is now in press.

An article, "The determination of antimony in rubber goods," written by members of the Bureau's staff, was published in Rubber Age and Tire News, vol. 8, 1920; Rubber, Engineering Production, vol. 2, part 1, 1921; India Rubber Journal, vol. 15, 1920.

An article, "An improved method for the determination of the total sulphur in rubber goods," was published in Rubber Age and Tire News, vol. 9, part 2, 1921.

LEATHER.

This work is concerned with the investigation and testing of leather and leather goods, to determine the physical and chemical properties and relative durability of different kinds of leather upon which to base standards of quality.

Sole Leather.

The investigation to determine the durability of leather tanned and filled with vegetable tanning materials as compared with leather tanned and filled with sulphite cellulose extract is nearly completed. Eighteen hides were prepared for these tests by three tanneries. Alternate sides of the different hides were filled with sulphite cellulose extract, while the remaining sides were filled with a mixture of chestnut wood and quebracho extracts. The results obtained from approximately 250 service tests on soles are as follows:

[Results expressed in day's wear per iron (unit of thickness equal approximately to one forty-eighth of an inch).]

Lot No.	Vegetable tanning material filler.	Sulphite cellulose extract filler.
1	8.0	7.5
2	7.2	7.4
3	7.6	7.8
4	6.5	6.4
Average	7.5	7.3

From the results of these tests it can be stated that the sulphite cellulose extract used in these tests as a filler for sole leather does not materially affect its durability.

The results of 20 service tests made to compare the durability of waterproofed and nonwaterproofed oak sole leather showed that the waterproofed soles outwore the nonwaterproofed soles by 2.7 per cent. This difference is negligible, and the results tend to disprove the contention that waterproof dressing a sole prior to its application to the shoe will increase its durability.

A series of tests made on the laboratory wearing machine with different samples of sole leather showed that the interior portions of sole leather have a greater resistance to abrasion than either the grain or the flesh sides. The results of these tests were published as Technologic Paper No. 166. It is of interest to note that a series of tests of similar nature made by the British Boot, Shoe and Allied Trades Research Association gave essentially the same results.

Upper Leather.

An investigation of the suitability of shark-skin leather for shoe uppers is still in progress. Several pairs of shoes which have the uppers of one shoe made with shark-skin leather and the other with calfskin leather are being subjected to actual service tests. From observations made up to the present time it appears that the shark leather is as durable as calf leather and has the advantage of not scuffing or peeling. Hence, its impairment in appearance is less rapid. The shark leather referred to is a "grain split," and laboratory tests show that it has greater tensile and tearing strength than calf leather.

A quantity of hogskin leather degreased in a vacuum chamber and then chrome tanned is being made into shoes for an investigation of the comparative durability of hogskin and calfskin uppers.

Membrane for Air-Speed Recorders.

The results of tests made to determine the suitability of leather prepared from the colon of a cow for use as diaphragms in air-speed indicators show that the leather is affected considerably by cold temperatures. The effect is greater as the tautness of the leather is increased. The leather is also porous to some extent. These facts exclude the use of leather where the characteristics of the indicator depend upon the elastic qualities of the leather. It is considered that lightness and pliability of the colon leather would make it valuable for use in instruments when the readings are independent of elastic qualities of the leather.

Rabbit-Skin Leather.

Several samples of both domestic and Australian rabbit skins were examined during the year. Physical tests showed that the tensile strength of these leathers was low, averaging from 1,200 to 2,000 pounds per square inch, and that the tearing strength was also low. Raw skins tanned in the laboratory gave the same results. In general, the surface of the skins contained many defects which would make the use of the full-grain leather unsatisfactory. Suede and embossed finishes cover these defects, so as to make the leather suitable for novelties. The use of rabbit skins for shoe uppers would not be economical on account of the small size of the skins.

Preservative for Shoes.

An investigation of various leather preservatives for use on Army shoes was made for the War Department. Of the different samples tested the one consisting of a mixture of sulphonated castor oil, neat's-foot oil, and mineral oil appeared to be the most satisfactory.

Specifications.

At the request of the U. S. Public Health Service specifications were prepared for calf art leather, sheepskin art leather, russet lining leather (calf), sheepskin lining leather (skivers), cowhide tooling leather, and calf tooling leather. A specification for black and russet strap leather was prepared for the Panama Canal. A standard specification for vegetable tanned leather belting has been developed. This specification has received the indorsement of the Association of Leather Belting Manufacturers, and it will be published as a Bureau circular.

Publications Issued.

Tech. Paper 166, "Laboratory wearing tests to determine the relative wear resistance of sole leather at different depths throughout the thickness of a hide."

Routine Tests.

There were tested during the past year 166 samples, including harness leather, leather belting, ledger binding, straps, packing leather, artificial leather, rawhide lace leather, sole leather, fishskin leather, sheepskin garment leather and bridle leathers.

TEXTILES.

General Facilities.

The section has for the past two years been concentrating on the development and extension of its equipment in order to meet the wide variety of demands made for information concerning the many fibers, yarns, and fabrics used in the textile industry. Perhaps the one greatest advance which has been made is the establishing of a testing room where the temperature and relative humidity can be accurately controlled.

The installation of the laboratory cotton mill has been completed, and experimental fabrics are being made when necessary in order to secure samples for experimental work. The section is now prepared to take up problems relating to manufacturing and testing in practically all of its phases.

Specifications.

Specifications have been prepared for the War Department, Navy Department, and the Panama Canal covering a wide variety of textile materials. In practically all cases it was necessary to conduct an investigation to determine what properties were desired before specifications which would give these properties could be recommended. The materials for which specifications were prepared and recommended include mattress ticking, cloth for Army insignia, elastic webbing, tarred marline, cloth for musette bags, rubberized sateen, webbing, street-sweepers' brooms, caulking cotton, flax and ramie cord.

National Association of Dyers and Cleaners.

The National Association of Dyers and Cleaners have offered their cooperation in the multitude of problems on the conservation of textiles which are confronting the dyers and cleaners and which should also receive the attention of the wearer or consumer. No definite program has been outlined as yet, due to the necessity of establishing a permanent cooperative organization, which is most essential for the success of the project.

Cooperation with the National Association of Woolen Manufacturers.

Considerable work has been done for the National Association of Woolen Manufacturers on problems submitted pertaining to the manufacture and the properties of their finished fabrics, together with methods for measuring these properties. The problems submitted are very comprehensive and require considerable time. Laboratory requirements in the form of test methods and apparatus are now under way, and pleasing progress has been made. Renewed efforts are now in progress to derive a program in order to arrive at an earlier solution than was planned.

Annual Technical Textile Conference.

A new committee was formed this year from the leading technical textile men in an attempt to broaden the scope of the work to be taken up by the committee for these annual conferences and the assistance to be given to the industry on technical matters. It was the opinion of the committee that a permanent committee and conference with associations should be established. In taking up these new plans the time necessary would not permit the annual May conference to be held, but such a conference will be held during the coming year.

Microscopy of Textiles.

Microscopic and photomicrographic methods are becoming of greater importance and are being more generally employed than ever before in the study of various problems arising in the manufacture and analysis of textile fabrics. This section has been able to make a more thorough study and analysis of the properties of balloon and airplane fabrics by means of photomicrographs of these materials than it otherwise could have done.

In the study of textile fibers and the analysis of fabrics for fiber composition the microscope is indispensable and is becoming more generally so regarded. In order to promote the intelligent and systematic use of the microscope in this field, this section is preparing a series of photomicrographs of the textile fibers, which are intended to show as clearly and distinctly as possible their physical characteristics, such as relative length and diameters, markings, thickness, and regularity of walls, shape of ends, etc. For this purpose, of course, the individual fibers are used and not a bundle of fibers. It is also thought that considerable information regarding the standard grades of some of the fibers, such as wool, may be disseminated in this way.

The Bureau is constantly adding to its collection of authentic samples with which comparisons of various fibers are made for iden-

tification. During the year the Bureau requested and was permitted to gather a large number of fur and hair samples from the National Museum and also obtained from the Zoological Park several samples of hair from animals which have been domesticated in several foreign countries. The numerous additions to the collection of hair fibers afforded an opportunity for comparisons in identifying fiber contents of press cloths made up almost entirely of hair fibers.

Balloon Fabrics.

Investigations on experimental fabrics have been continued throughout the year. Work on problems for the Aircraft Divisions of the Army and Navy Departments has progressed, so that several problems are finished while others will have to be continued in the next fiscal year.

The problem on the effect of thread count on permeability has been completed. Cloths varying from a high number of threads per inch to a comparatively low number were woven by the Pierce Manufacturing Co. and made up into balloon fabrics by the Goodyear Tire and Rubber Co. These fabrics were tested and then exposed to the weather for 210 days, test samples being cut off at the end of every 30 days. From these tests the deterioration of the fabrics was followed until they had reached a point where they were of no use as balloon fabrics. The results, while not so conclusive as it was hoped they would be, indicated that a fairly high thread count, about 120 by 130, is necessary to secure the required strength and life of the fabrics. Several interesting points were brought out which will need further study before they can be accepted.

Exposure tests on 26 frames of balloon fabrics doped and coated in various ways are now under way. Ten-day readings of the tautness of each frame are being taken in recording the loss to permanency of tautness, a property of resistance to deflection. The instrument used in this investigation, which is being conducted in an endeavor to find a substitute for the present goldbeater skin fabric, was developed and designed in the textile section.

Assistance was also given to the Army Balloon Service in testing a large number of representative specimens of balloon cloth which were in storage and the most of which were to be sold as surplus. Over 2,000,000 yards were to be sold, while the best cloths were to be retained.

A short article was completed on the bursting of balloon fabrics, a test which in theory was to represent the actual conditions of a fabric in service.

An interesting problem in connection with the bursting test used on balloon fabrics at the Bureau for the last several years has been presented. The balloon-bursting test which is used to determine the stresses and strains of a particular kind of fabric of given size and shape under gas pressure has proved invaluable in this field. The problem of ascertaining whether and for what length of time a fabric would hold up after a small hole, such as a bullet might make, has been made in the covering, resulted in a study of the effect of size, shape, and orientation of a hole with respect to the systems of threads on the resistance of the fabric to tear. From the results of this investigation a standard tear test was evolved.

Length Tolerance of Blankets.

An interesting problem was presented to this section by the blanket trade. It was desired to find out what factors entered into a very marked variance in the length of blankets and to what extent the manufacturer was responsible for these changes. This was not only subjecting them to loss through breach of contract suits, but in their endeavor to overcome their difficulties the blanket company was adding several inches to the normal length, so that the blanket might be longer rather than shorter than the stated length.

This was taken up in two phases. The first, a laboratory investigation, studied the effect of humidity on the length of a finished blanket, using four of their regular types. The second was a study of the effects of manufacturing processes and conditions. This latter part is still in progress. Members of the Bureau's staff went to the mills and after a brief preliminary survey mapped out a program which will probably give the necessary data for solving the problem. These data are being collected by representatives of the mills.

This investigation is considered a very valuable one for this Bureau. It was taken up, first, because it was thought it might prove to be the entering wedge in demonstrating the result of scientific consideration of mill problems on the quality of the product. It is also giving this section some very valuable data in regard to mill conditions as affecting quality in general. The results of this investigation will be sent to each of the blanket manufacturers for the purpose of having inserted in future contracts a statement regarding length and conditions affecting it, so that any further litigation may be avoided.

Utilization of Low-Grade Cottons.

Preliminary work has been started in an endeavor to collect some data on the important problem of the utilization of low-grade cotton. Those interested appear to be very willing to cooperate in this investigation, and considerable work can be done to assist the grower to dispose of his material, which at this time has little or no market. This would result in the designing of cheaper fabrics, thus lessening the cost of living. No definite program has been outlined, but it is hoped that conditions will permit the undertaking of considerable work this coming year.

Cloth Variables Investigation.

In the manufacture of cloth there are a great many variables due to machine design and construction of the cloth, all of which have some effect on the quality and strength. Heretofore most of these variables have been disregarded, resulting in a lack of uniformity in the product of a mill and making it very difficult for two mills to produce a like product.

The study of the effect of these variables on the properties of the finished cloth is very involved, and until recently the Bureau was not in a position to take up this problem. Now that the section has a small experimental cotton mill, where these variables can be controlled, the problem has been taken up. As a starting point it was decided to take samples of cloth similar in many respects and by

changing one variable at a time determine the effect on the properties of the cloth. Samples have been made, and the effect of crimp, twist in the singles and ply yarns, and threads per inch is now being determined. This problem will probably extend over a period of years, but the results will be of value as they are obtained and need not necessarily wait on the completion of the investigation.

Filter Press Cloths.

The problem of a standard oil percentage and moisture regain for press cloths was brought to the Bureau's attention by the users of press cloths, who presented it with the purpose of having a fixed basis for transactions between manufacturer and user to eliminate arguments and litigation in the buying of press cloths.

A number of samples were analyzed, and the results are being studied to accomplish the desired results. It is planned to submit a preliminary report to a committee of users and manufacturers and have them render an opinion in regard to the conclusions to be drawn. This seems to be the best method of handling a problem such as this, for it is realized that any findings that the Bureau would submit to the trade might be rejected by either one side or the other. This committee, which includes the principal users and manufacturers of press cloth, will give such findings as are agreed upon more authority.

Properties of Cotton Fibers of Different States of Maturity.

A preliminary program was outlined to study the spinning possibilities and physical properties of cotton fibers before and after they have fully matured. Microscopic examination shows that a cotton fiber has a different cell construction before it is wholly ripe, and for this reason there has been a demand by the industry for information concerning the relative value of the fiber in this state as to its manufacturing possibility and performance. Results of this work should be of great assistance in the attempt to shorten the picking season, which lasts over a period of three or four months. One of the benefits to be derived from this investigation would be that the materials could be classified according to their spinning possibilities and performances, giving the manufacturer a definite commodity for his needs. The results could also be incorporated with the effect of patent processes for chemical ripening of cotton. Due to the lack of cooperation, no great progress was made, and the investigation was confined to a preliminary outline which proposed the formation of a committee of growers and harvesters for the carrying on of the outside work.

Suitability of Paper and Cotton Bags in Relation to Burlap Sandbags.

In cooperation with the paper section of this Bureau work on the study of the requirements of sandbags in trench and barricade warfare was completed during the year. The study has special reference to the cost, availability, methods of manufacture, durability in transportation and handling under all conditions of weather and location for a period of predetermined life. The work was undertaken at the request of the ranging and camouflage unit of the War Department, who are conducting the actual service tests,

which as yet have not been reported. A final report under this heading has been compiled for the laboratory work.

Florida or Spanish Moss.

At the request of the War Department an investigation of the properties of Florida or Spanish moss was carried out to determine its suitability as a mattress filler in place of hair or cotton. It was found that when properly used the moss was inferior to hair, but was more satisfactory than cotton.

Numbered Cotton Ducks.

Through cooperation with several manufacturers of numbered or wide ducks, who furnish all of the material, a study of most of the commercial ducks of this class was made to find out what constructions gave the greatest strength and what variations occur between the same number of duck in the different makes. The results will be used in preparing specifications which will be recommended in place of the existing specifications, which have proven to be unsatisfactory.

Testing of Cotton Ducks.

In conjunction with a large private textile laboratory a series of tests was made to determine the effect of different shapes and sizes of the test specimen on the indicated strength of duck. All of the ordinary methods of test and several new methods were tried out with very interesting results. It was found that each method of test and each different shape of specimen introduced a variable, the value of which would be difficult to determine except in the case of the strip method of test. The correction factor for the error in the strip method of test can be readily determined, but for ordinary testing can be disregarded, as the correction factor is less than the variation between the individual test specimens.

Artificial Silk.

Representatives of a fiber silk company used the facilities of the bureau's testing room to run a number of tests on strength, elasticity, twist, and weight of samples made at their plant for the purpose of improving the product, if possible, in accordance with the results obtained. The Bureau views such projects with satisfaction, since they show that the industry is applying scientific methods more and more in the working out of their problems and the improvement of their products.

Investigation on Waste Silk Materials.

The Bureau was asked by the Ordnance Salvage Board of the War Department to determine the possibility of spinning into commercial spun-silk yarns a large quantity of waste silk which was purchased to be spun into yarn for cartridge bags. A representative went to the Army base depot where the material was stored and outlined the work necessary. Boiling-off tests were made at Philadelphia in cooperation with a spun-silk manufacturer. The final report to the Ordnance Salvage Board contained a complete classification of waste silk used in commercial spun-silk yarns and the

amount of commercial yarn that could be obtained from each type of waste and also a complete set of photographs of both the commercial wastes and the Ordnance Salvage Board wastes for visual comparison.

Chemical Retting of Flax.

Assistance was given to a new project for the chemical retting of flax for use in manufacturing linen yarns. Physical tests were made to determine whether or not the rapid chemical action has any detrimental effect on the strength of the fibers. Several numbers of yarns were tested and also a number of samples of woven fabric. This work was done in conjunction with exhaustive and expensive experiments by private parties in an attempt to develop the linen industry in America and which will probably continue for some time in the future. The Bureau is glad to offer any assistance possible in the furthering of this industry.

Pompier Belts.

The fire department of the District of Columbia experienced some difficulty in the buying of pompier belts in specifying just what loads and what service a belt of this nature should reasonably be called upon to furnish. A study was made of the properties of the belts now in use, and recommendations were made for several changes. The Bureau also took up the subject of certain periodic service tests on these belts and tests on life nets.

Asbestos Brake Linings.

Samples of abestos brake linings were submitted for test to determine their suitability for the purpose intended. The percentage of asbestos and other materials was obtained, the ability of the samples to absorb water and oil and to permit ready evaporation was determined, and the results compared in the various samples.

Conveyor Belts.

In conjunction with the Post Office Department the Bureau is collecting data preliminary to writing specifications for conveyor belting for use in post offices. The Bureau is conducting the laboratory tests and outlining the service tests, while the Post Office Department is furnishing the belting and is carrying out the service tests. Test belts made up of segments of several types of belt are now in use, and it is expected that at the end of 18 months the belts will have shown enough depreciation to be taken out. The laboratory tests are nearing completion and will be checked against the service tests as rapidly as possible.

Umbrella Cloths.

Some work was done on the possibility of replacing the high-priced umbrella cloths with cheaper fabric, such as balloon fabric. Physical tests were made for comparative purposes, and the results showed that the balloon fabric was superior in most cases. There were a few essential requirements which were lacking but which could be corrected in the original design. This short investigation brought out the desirability of a study of the properties of a material according to its particular use.

Cloth-Measuring Tapes.

Cloth-measuring tapes are usually made from flax or hemp with or without metal threads, which aid in keeping the tape unelastic. In an endeavor to produce a satisfactory cotton tape special yarns were secured and are now being woven at one of the mills. The preliminary results would indicate that a satisfactory tape can be made of cotton, but further tests must be made before any conclusions can be drawn.

Printer's Blankets.

An investigation of the printer's blankets used at the Bureau of Engraving and Printing has been undertaken because of the difficulty which has been experienced by the Government in purchasing satisfactory blankets. The results of this investigation will be used in preparing specifications which will insure a blanket which will meet the requirements and which can be duplicated when necessary.

Routine Testing.

Over 5,500 samples were tested during the past year, principally from Government departments and organizations, of which the Panama Canal, War Department, Navy Department, and Post Office Department were the chief contributors. The tests covered the whole field of textiles, including fibers, yarns, and an unusual variety of fabrics, as well as made-up materials, such as blankets, handkerchiefs, table linens, hosiery, etc. While most of the tests used to estimate the value of the Government's purchases in textiles, especially the checking of samples to the specifications under which they were bought, are of a routine nature, their importance in almost all of the Bureau's research problems has been realized. The majority of the researches are helped materially by additional data furnished by the routine testing, and, considering the number of samples which have been tested and the care and accuracy necessary in their preparation, it is very evident that routine testing occupies an important place in textile laboratory work.

Information.

One of the Bureau's activities has been to prepare and furnish information on scientific and technical subjects pertaining to textile mill and laboratory equipment and also to aid in standardizing specifications and performances of textile materials. It is the tendency of the textile industry to increase their efforts toward the adoption of scientific methods and research in the improvement of their products. Consequently, demands on this section have been multiplied for solution of technical problems and for information.

Cooperation with Societies and Textile Organizations.

Members of the textile section have cooperated with the following Societies: National Research Council, American Society for Testing Material, American Society of Mechanical Engineers, National Advisory Committee for Aeronautics, National Association of Woolen Manufacturers, National Association of Cotton Manufacturers, National Association of Wool Growers, National Association of Dyers and Cleaners, Cotton Duck Association, Oklahoma Cotton Growers' Association, and Interstate Cotton-Seed Crushers Association.

Publications.

No extensive publications were made during the past year because of the time required for solution of problems under way. Plans have been made for a series of publications for the coming year.

PAPER.

General Conditions.

Practically all the equipment purchased last year has been set up and is in operation. The addition of this equipment to the paper mill—300-pound beater with suitable chests, supercalender stack, sheet cutter with lay boy, four-plat flat screen, and additional motors—has made it possible to work more efficiently. The methods of obtaining and tabulating data in the paper mill have been systematized and a much larger amount of data is now being obtained. The constant temperature and humidity room has made it possible for all physical tests to be of greater accuracy than ever before, and the equipment has been adjusted and changed somewhat to produce greater uniformity of conditions.

Stain for Sulphate Pulp in Paper.

Kraft paper may or may not be made of so-called "Kraft" or sulphate pulp, and it is somewhat difficult to determine whether such paper is produced by using sulphate or sulphite wood pulp. The development of a method for this purpose has been completed and the data published (Bureau of Standards Technologic Paper 189). The fact that a suitable mixture of two dyes (malachite green and basic fuchsine) stains the two pulps differently is used as a basis for differentiating between the two pulps. The selective stain colors sulphate pulp blue or blue-green, and unbleached sulphite pulp is colored purple or lavender. It is therefore possible to estimate the relative proportions of the two fibers when present. The procedure consists of disintegrating the sample of paper by chemical and mechanical means, so that the fibers are separated. A small group of these fibers are then placed on a microscope slide and treated with the prepared stain under certain conditions. When properly prepared, the sulphate and unbleached sulphite are easily distinguished under the microscope, and by use of standard samples it is possible to estimate the proportions of the two kinds of fibers. The chief difficulty in the past has been that similar species of wood are used in the production of both kinds of pulp, and it is therefore necessary to produce some distinctive color, as the fibers have much the same shape and markings.

Condenser Paper.

Manufacturers of electrical instruments have found it difficult to obtain paper suitable for use in electrical condensers. The two important qualities of a paper for this purpose are that it should be relatively thin (0.0005 inch) and free from conducting particles. Commercial mills are able to produce paper of this thickness, but find it difficult to keep out the conducting particles. A series of runs were made using raw "shirt cuts" and linen rags. Beater rolls with iron or phosphor bronze bars were found to be unsatisfactory for this pur-

pose, as the paper contained a large number of conducting particles. A special composition roll (concrete and flint) was tried and found to give much better results. Difficulty was experienced with the Fourdrinier machine in obtaining a paper of suitable thickness, although paper was obtained of about 0.0008 inch in thickness and having about two conducting particles per square foot. A special attachment will be obtained for the paper machine to make it possible to produce paper of the required thickness. The conclusions drawn from this work are that this paper should be made of new "cuttings," carefully dusted and sorted after cutting, washed, and beaten with stone or composition roll and on a Fourdrinier machine with pick-up felt attachment to carry the web from the couch to the dryers. Extreme care must be exercised to keep all dirt and metal from the stock during the process, and clean, new stock should be used.

Sizing Quality of Paper.

Certain materials, such as rosin, starch, glue, etc., are added to paper to make its surface suitable for writing and printing purposes. This quality is called sizing, and the methods in general use of determining this quality of paper are unsatisfactory. The development of a satisfactory method is very desirable, especially as a means of studying the effect of sizing materials in the manufacturing process. Considerable progress has been made since last year along this line, but it has been found that the large number of factors which influence the electrical conductivity method make it very difficult of interpretation. A different kind of method has been investigated, and it is thought that this latter method will not only give values for the sizing quality of paper but will permit of interpretation of the curves obtained by the conductivity method. The development of a method for obtaining a numerical value for the sizing quality of paper will make it possible to define this quality in specifications, to produce more uniformly sized paper during manufacture, and to investigate the effect of different sizing materials, their efficiency, and the effect of the whole manufacturing process (especially beating and drying) upon the sizing quality of paper.

Paper Testing.

Due to the large number of requests, a circular (No. 107) on "The Testing of Paper" was prepared. This circular contains information relating to the methods of testing and the apparatus employed in the paper laboratories of the Bureau of Standards for the routine testing of paper. In the introduction a brief description of the raw materials used, the size and importance of the paper industry, and the general groups or classes of paper are given. The classification of paper is only of a general nature. The purpose of such tests and the development of methods of testing is touched upon and suggestions are given as to the methods of developing specifications.

The testing of paper is divided into three groups, and the methods are classed as physical, chemical, and microscopical. Under each group the various standard methods are given in detail, with photographs of apparatus employed. No attempt is made in this circular to interpret results of tests. It is brought out that changes of tem-

perature and humidity affect the physical qualities of paper, and for this reason a constant temperature and humidity room has been installed. It has not been possible to give the relation between humidity and temperature changes and the physical characteristics of paper, but it is hoped to have this information available later. The chemical testing of paper is concerned with the determination of the amount and kind of filler or loading material used and the amount and kind of sizing in the paper, and both qualitative and quantitative methods are given in some detail. It is desirable to know the kinds of fibrous materials out of which a sheet of paper is made, and for this purpose certain stains are used to color the fibers on a microscopical slide. The procedure is given and suggestions are made as to the value of microphotographs. A short working bibliography is included, as well as regulations for tests and methods of sampling and submission of samples for test.

Paper Bags for Lime and Cement.

The development of suitable methods for testing paper bags for lime and cement was continued from last year, and the data obtained have been published (Bureau of Standards Technologic Paper No. 187). This paper contains information relating to the methods of testing and the apparatus employed in determining the quality of paper bags for lime and cement. A brief description is given of the ordinary tests performed on paper, such as weight, in pounds, of the standard-size ream, 25 by 40—500, bursting strength in points, tensile strength in kilograms, stretch in centimeters, folding endurance in number of double folds, percentage of fiber composition, percentage of ash, and percentage of rosin sizing. A special test is developed for giving numerically the stresses and strains that the paper of these bags undergo in service. This test is called a resiliency or endurance test. A service test is also given to determine the breaking strength of the paper when the bags are filled and dropped. A comparison is made of the results of this test with the results of the above resiliency test. Another service test is developed for determining the strength of the adhesives used in these bags. The results of all these tests are tabulated, and from these data the very best quality bags are chosen. In the conclusions special consideration is given the choice of best bags in determining the characteristics of a good quality bag, and specifications are drawn up accordingly.

Paper and Cotton Bags for Use as Sandbags.

On September 6, 1919, a request was made by the Corps of Engineers, War Department, for information from the Bureau of Standards in regard to the development of a substitute for the jute fiber used in the manufacture of sandbags and burlap. Since the raw material is not found in this country and as the manufacturing of jute fabric is carried on abroad it seemed desirable that a material should be available which could be obtained at all times in the United States. A superficial survey indicated that either woven-paper fabric or crinkled solid paper were promising materials for this purpose, but that commercial manufacturers had done little experimental or development work along this line. Since the paper section of the Bureau of Standards was at that time conducting an investiga-

tion on paper bags for lime and cement, and for that reason was in a position to undertake an investigation into a material for use in sandbags, the Chief of Engineers placed a formal request with the Bureau of Standards to carry on the above investigation. A conference was then held between the officer representing the War Department and representatives of the paper and textiles section, Bureau of Standards. In this conference it was decided that representative samples of paper, cotton, and burlap should be obtained from the manufacturers. The investigation was carried on jointly by the paper and textile sections.

All tests in this investigation, with the exception of tests on wet material, give results which indicate that paper 16730, a rope paper, would be a very good substitute for burlap. This paper, however, is very weak when it becomes wet. If this paper could be waterproofed this difficulty would be eliminated, but the waterproofing of paper at the present time is in the experimental stage. Many formulæ for waterproofing have been patented, but when they are tried out in the paper mills it is found that they either do not waterproof at all or destroy the suitability of the paper for the purpose for which it is to be used. Practically all the work on waterproofing to date has dealt only with the chemical treatment of the fiber either before or after the paper has been made, while very little work has been done on the scientific control of the beating process in the manufacture of the paper. It is planned by the paper section to investigate this problem thoroughly and by the use of chemicals along with the scientific control of the beating to manufacture, if possible, a paper similar to paper 16730 and yet waterproofed sufficiently to make it suitable in every respect for sandbags. Since paper 16730 contains 30 per cent manila and jute rope stock, which might be hard to obtain in time of war, since the jute raw material is not under United States control, it is probable that the paper section will also undertake to manufacture a 100 per cent sulphate fiber paper that will be as strong as the above rope paper.

Waterproofing of Paper.

In connection with the investigation of a paper bag suitable for use as a sandbag, it was found necessary to develop a paper that would retain a reasonable strength when wet. The method of determining this quality was to compare the results obtained by testing the paper when dry and after soaking in water for one hour. It was felt that an increase in the amount of rosin sizing added to the beater would increase the wet strength of the paper. A series of runs was made, using different percentages of rosin and maintaining the other factors as nearly constant as possible. It was found that the addition of 6 per cent of rosin increased the wet strength to a ratio of about one to four, whereas the ratio in the case of commercial papers tested for this purpose was one to twelve or fifteen. The increase of wet strength seems to indicate the advisability of continuing this work. A sufficient quantity of this paper should be manufactured, made up into bags, and given practical tests.

Tearing Strength of Paper.

As indicated in the previous annual report, the development of a method suitable for determining the tearing strength of paper is very desirable. This work was continued during the year and an-

other type of instrument has been investigated. The results of all this work will shortly appear in publications of this Bureau. Aside from the mechanical features of the machines themselves, it has been found that this test is affected by the rubbing of the sample during the tear when more than one ply is used, and also that the width of the sample affects the test. This latter is probably due to the assistance given by the fibers adjoining those being torn and seems to extend out from the place of the tear. Although most of the instruments sold for this purpose are satisfactory for certain work, it is thought that the two factors mentioned above must be considered before a really accurate machine will be available.

Newsprint.

The possibility of using sulphate pulp in place of sulphite pulp in the manufacture of newsprint was investigated. Various combinations of ground wood, news sulphite, and sulphate pulps were made into newsprint. Small batches were run and the results were not very conclusive, especially due to the fact that the machine could not be run over 75 feet a minute, while newsprint is normally manufactured at from 600 to 1,000 feet a minute. However, as far as the tests made were concerned and not taking into account the slow speed of the machine, it was not thought objectionable to use sulphate pulp for newsprint.

Testing of Blotting Paper.

The method of testing the absorbent quality of blotting paper generally in use in the Government service is not satisfactory, as it does not take into consideration the thickness or cross area of the sample being tested. A study has been completed on several methods of determining this quality, and the data will be published in the near future. The addition of clay to the "furnish" for blotting paper generally produces a paper with a relatively high absorbent quality, but such a paper will not be very satisfactory for repeated blottings on the same spot. It is thought that this factor must be considered in the development of specifications for this grade of paper.

Carbon Paper.

With the cooperation of the Chemistry Division an investigation of methods of testing carbon paper has been undertaken. Not only are various grades of base tissue used and many kinds of coatings, but there are few reliable methods for determining the quality and efficiency of carbon paper. Practical life tests by typists are not always possible, and the analysis of the coating is of little value. In addition to this, different kinds of carbon paper should be used for different work and different weight paper should be used in connection with carbon paper for various uses. The life of a sheet of carbon paper is important, as well as the number of manifold copies a certain grade will make. The assistance and cooperation of the manufacturers has been obtained, and it is hoped that the whole question of carbon paper may be put on a more technical basis.

Testing and Information.

Routine Testing.—A suitable personnel is maintained to handle the large number of samples of paper submitted by the Government and the public for test. This work is well standardized, and nearly

all samples are reported within a week of receipt. It is difficult in most cases to obtain suitable samples for test, and this applies to a large number of the Government bureaus. Emphasis has been laid on the necessity for proper sampling, which is as important as the testing. Below is given a statement of tests during the fiscal year:

	Number of samples.
Government Printing Office	2,381
General Supply Committee	363
Post Office Department	173
Panama Canal	89
Department of Commerce	76
Department of Agriculture	72
United States Shipping Board	45
Navy Department	26
Treasury Department	22
War Department	14
State governments	8
Bureau of Engraving and Printing	2
Miscellaneous	36
Bureau of Standards	656
Total for the Government	3,963
Total for the public	298
Grand total	4,261

Information.—A large amount of information is given to the general public and to the Government through correspondence and to individual visitors. It is impossible to estimate the time spent in this connection. A short list of some of the more important subjects covered is given below:

The increase in the quantity of cotton linters used for paper manufacture has been reflected in the increase in the number of requests for information about them. Second-cut linters, when kept clean and properly prepared, are suitable for several grades of paper, including book, blotting, and writing. It has been found by experience that they must be treated somewhat differently in the beater than rag stock.

Data and information have been furnished the Siamese Legation to enable the Siamese Government to purchase in this country necessary equipment for an experimental paper mill, to use native materials, such as rice straw, lalang grass, and wild banana.

Details of necessary equipment for a paper-testing laboratory have been furnished, including the various types of instruments that are most satisfactory.

In microscopy and photomicroscopy of paper-making fibers stains are necessary for identification and to bring out the characteristic markings of the fibers. Information in regard to these has been furnished.

Several samples of paper have been submitted for identification as to source of manufacture. This is not always possible, but in some cases the paper is so characteristic of a certain mill that it may be done. The comparison or contrast of two papers thought to be the same is easier.

Considerable information and assistance has been given the Tariff Commission in regard to trade customs, nomenclature, etc.

A large number of inquiries in regard to various paper-testing methods and suitable testing instruments have been received. The publication of the accepted methods (Bureau of Standards Circular No. 107) will somewhat lessen the burden of these inquiries.

Because of the shortage of raw material for paper manufacture during the first half of the fiscal year there was considerable interest shown by the public in the development of various grasses, straws, and fibers for this purpose. In most cases it was not necessary to consider the manufacture of paper from these fibers. Paper can be made of nearly any vegetable fibrous materials, and most of the so-called "new" fibers have been tested during the last hundred years. In practically all cases the cost of collection, the low yield, the cost of conversion into paper, and the low grade of paper that might be obtained would not warrant investing money in a mill for this purpose.

Considerable interest has been expressed in clays for fillers and for coating, but it has not been possible to give any definite information on the actual value of any clays submitted for this purpose.

Suggestions and information on specifications have been given in reference to wrapping paper for department store use, loose-leaf ledgers, and various book, writing, and bond papers. However, aside from specifications for Government use, no definite specifications have been recommended as yet for general use by the public.

Information has been given on the following grades of paper: Cigarette, book, bag, blue print, blotting, container board, index bristol, bond, kraft, manifold, ledger, corrugated board, India, roofing felts, newsprint, manila, wall board, drawing, carbon, straw, bristol board, waxed, envelope, coated book, insulating, Jacquard cards, etc.

Conferences.—Several conferences were held during the year in reference to the specification for paper to be purchased by the Government Printing Office. Recommendations were made that a 5 per cent tolerance be permitted on weights, and that the quantities specified should be reasonably definite.

Monthly meetings have been attended and tentative specifications for lime and limestone for use in the manufacture of sulphite pulp have been submitted.

Assistance was given to the General Supply Committee in regard to the specifications for paper in Class I. An attempt was made to make these more uniform and have them conform as much as possible to trade practices and grades.

A revision of the specifications of the Post Office Department for the purchase of envelopes for departmental use was recommended. These specifications were faulty in some cases and were not uniform. It was recommended that manufacturers' names and mill brands be left out of all proposals, and that the awards be made on bids submitted on specifications.

To increase the value of the work of the paper section to the paper industry it was requested that the American Paper and Pulp Association appoint a committee to cooperate with the section. Two conferences have been held, and the whole question of research work, standardization, and specifications is more clearly understood.

Relation to the Paper Industry.

Definite contact with the paper industry is being maintained through membership on committees of the Technical Association of the Pulp and Paper Industry and through the advisory committee of the American Paper and Pulp Association. Closer cooperation with and greater service to the paper industry is gradually being accomplished, and the opportunity of assisting the industry is greater than ever before. Actual cooperation with the mills on larger problems will follow more and more.

Publications.

The following is an enumeration of the publications issued by this section:

The testing of paper, B. of S. Circ. 107.
A study of test methods for the purpose of developing standard specifications for paper bags for cement and lime, B. of S. Tech. Paper 187.
Method for differentiating and estimating unbleached sulphite and sulphate pulps in paper, B. of S. Tech. Paper 189.
Suitability of paper and cotton bags in relation to burlap bags for sand, Paper Trade Jour., May 19, 1921.

LUBRICATING OILS.

Standardization of Instruments.

A general review of the work in standardizing methods of test was given in a paper read at the annual meeting of the American Petroleum Institute, Washington, November, 1920, and published in Journal of the Society of Automotive Engineers, volume 8, page 481, 1921.

A paper on the "Flow Through Short Tubes" was published by the American Society of Civil Engineers, No. 21–C, March, 1921. The laws of flow, here discussed, form the basis of all work on the calibration of efflux viscosimeters.

The paper on the MacMichael Viscosimeter, mentioned on page 226 of last year's annual report as prepared in collaboration with the Bureau of Mines, was published by that Bureau in Reports of Investigations, Serial No. 2201, January, 1921.

The new Saybolt fuel oil viscosimeter is described in report of committee D–2, American Society for Testing Materials, 1921, and in Bulletin No. 5 (p. 24), committee on standardization of petroleum specifications.

Plasticity.

The subject of plasticity (as defined in Scientific Paper No. 278) is of interest in connection with lubricants, since greases are plastic. Much new information has been obtained in regard to the methods of measuring plasticity by the following investigations:

1. Report of an investigation of the consistency of starch and dextrin pastes will be published shortly in the Journal of Industrial and Engineering Chemistry.

2. The consistency of varnish, some samples of which are plastic, is discussed in Circular No. 127, Paint Manufacturers' Association of the United States (National Varnish Manufacturers' Association cooperating), June, 1921. This investigation was conducted at the

Bureau of Standards oil laboratory, and a special plastometer designed for this work is illustrated on pages 14 and 25 of the above-mentioned circular.

3. The consistency of fats used in cooking was investigated in cooperation with the Bureau of Home Economics, Department of Agriculture, but the results have not yet been published.

4. In a paper "On plastic flow through capillary tubes," by E. Buckingham, presented before the American Society for Testing Materials, June, 1921, the work of previous experimenters was discussed and a new equation proposed. Another paper in which the matter is treated in greater detail will appear shortly in the Journal of Industrial and Engineering Chemistry.

Physical Tests.

During the year routine tests were made on 661 samples for Government departments and special tests were made on 51 samples for private parties. Thirteen Saybolt universal viscosimeters were examined to determine whether the dimensions were standard.

Cooperative Work.

In addition to the usual cooperation with the American Society for Testing Materials and the committee on standardization of petroleum specifications, assistance was given the committee on prime movers of the National Electric Light Association in the preparation of specifications for steam turbine oils, published in their report.

Results of an investigation of the "float test" for finding the consistency of asphaltic material was reported to Committee D–4 of the American Society for Testing Materials, at whose request the work had been undertaken.

8. METALLURGY.

The Metallurgical Division concerns itself with research, investigation, and testing as related to metals and alloys, except built-up metal structures and the processes of extraction of metals from their ores. Its functions include the production of metals and alloys, both of the highest attainable purity and of commercial grades; the preparation and study of auxiliary metallurgical products, such as slags, included gases, molding sands, refractories and deoxidizers; the development of apparatus, instruments, and manufacturing appliances for metallurgical processes, research, and testing; the formulation and maintenance of those standards and specifications of interest to metallurgy; the determination of metallurgical constants and properties; the investigation of the performance of manufacturing units; the determination of the causes of failure and the study of the improvement of metal products; and the development of economical metal substitutes. The division has equipment for metallographic examinations of metals, such as microscopic analyses, including determinations of constitution, structure, and causes of failure; for thermal analyses, including determination of heating and cooling curves for location of critical points; for the various heat treatments, such as annealing, quenching, cementation, tempering; for various operations for the hot and cold working of metals, such as forging, rolling, and drawing, and for miscellaneous physical tests; for the usual foundry operations of molding and casting ferrous and nonferrous metals; and for other metallurgical processes, such as production of pure metals, welding, and determination of gases in metals.

GENERAL.

Position of the Metallurgical Division.

The Metallurgical Division concerns itself with experimental research and the acquirement of knowledge in fields related to products metallurgy as distinguished from process metallurgy, which last has to do with the extraction of metals from their ores and smelting and refining operations. The field covered is very large,

embracing not only manufacturing operations both for iron and steel, but also for nonferrous metals. An endeavor is also made, particularly in cooperation with specification-making bodies, to keep abreast of the times in the formulation of metallurgical standards and specifications for metallurgical materials.

The Metallurgical Division is already committed to the solution of a number of very important fundamental problems looking to betterment in metallurgical practice. Most of these problems have been outlined in collaboration with technical societies or groups specially formed for the purpose of following up progress in the various subjects.

Among the most important of these may be mentioned the investigation of the effect of sulphur and phosphorus in steel, which is being carried out in cooperation with the steel manufacturers, specification-making bodies, including the railroads and shipping interests and Government departments. This is a fundamental problem of the greatest economic importance to our steel industries. The investigation of the underlying causes and characteristics of corrosion of metals, which will involve elaborate laboratory research and extended field investigations in various soils with many types of material, is being outlined systematically under the auspices of a joint committee now being formed. In the welding of metals several industries, such as the street railways and shipyards, have come to realize that there are a great many problems of practical importance which can be solved only by extended scientific research. These problems are being outlined by committees representing the street railways, shipping, and manufacturing interests. The subject of gases in steel is one of the most baffling in all the field of metallurgy, and enough has already been done at the Bureau and elsewhere to emphasize the importance of this problem. There is in formation a committee advisory to the Bureau on iron and steel, and it is hoped that financial support may be forthcoming for the numerous important problems which ought to be studied at the Bureau's metallurgical laboratories. The investigations that the Bureau has carried out on railroad materials, particularly chilled-iron car wheels, ingot problems, and the rôle of temperature in metallurgical problems, have excited widespread interest and it is highly desirable to continue effective work along these and similar lines.

OPTICAL METALLURGY.

Metallographic Etching Reagents and Methods.

1. *Nonferrous Metals.*—This investigation, mentioned in last year's report, has been continued during the year. The results obtained for copper, which was the first type to be considered, were published during the year as a Bureau scientific paper. The second series, which included the copper alloys—that is, brasses and bronzes, nickel and its alpha alloys—has been completed, and the results will soon appear in published form. The principles underlying the etching of copper—that is, a slight solvent action and an accompanying oxidation—hold true for copper alloys and to a slightly less extent for nickel and its alloys. Some new etching methods

were developed for nickel, among which may be mentioned the use of concentrated hydrochloric acid, which in many cases gives results much superior to those obtained by reagents in more common use. The third series includes aluminum and its alloys. The study of this metal has already been started.

2. *Special Steels.*—The characteristic properties of many of the special alloy steels, including chromium and high-speed tool steels, depend upon the microstructural constituents which make up the alloy. In many cases the exact nature of some of these constituents is a matter of controversy. Special reagents for identifying such constituents under the microscope are necessary, and considerable progress has been made in this study, particularly in distinguishing constituents which are the result of nitrogen such as may occur in arc-fusion steel welds, from those caused by the carbon content, and in the development of suitable reagents for the carbides in the various special steels. Most of such reagents are of an oxidizing nature and very strongly alkaline in their reaction.

Deep Etching as a Means for Metallographic Study.

The microscopic features of steel revealed by the use of concentrated acid as an etching medium were discussed in last year's report. This method of etching has the disadvantage that the surface is very much roughened and the specimen can not be used for subsequent examinations without regrinding and polishing. An etching reagent consisting of an aqueous solution of ammonium persulphate was developed during the year by means of which most of the structural features of iron and steel which are ordinarily disclosed by "deep etching" may be revealed. The etching consists of a relatively light attack, and the specimen is not spoiled for subsequent examinations, as is the case in deep etching with acid. The results have been published as a scientific paper.

Structural Changes Accompanying the Tempering of Hardened Steels.

The structural changes which occur in hardened steels upon reheating (tempering) can readily be disclosed by special means, particularly by a measurement of the changes in different physical properties of the steel. The changes as observed by means of the microscope are relatively slight, and but few significant micrographs bearing upon this point have ever been published. This investigation, which is over one-half finished, is being carried out upon five different steels varying in carbon content, each of which was hardened at several different temperatures, and each of which subsequently received different degrees of tempering. Thus the effects of the three variables—carbon content, hardening temperature, and tempering temperature—upon the structural conditions and the hardness are being considered. Over 800 specimens are required for the complete study, each of which varies somewhat in its heat treatment, and hence in its microstructure.

Intercrystalline Brittleness of Soft Metals as a Result of Corrosion.

The results of the study of embrittled lead have been previously described in a Bureau scientific paper (No. 377). An investigation to supplement these results was carried out to show to what extent

the application of stress to the metal while subjected to corrosion aids in the deterioration of the material, and also the observations were extended to other soft metals besides lead—that is, aluminum, tin, and zinc. The results have been prepared for publication and will soon appear as a Bureau scientific paper. In general, it may be said that lead appears to be more subject to deterioration of this type than do the other metals studied. Aluminum, because of the impurities the commercial metal always carries, sometimes develops intercrystalline brittleness as a result of corrosion, but tin and zinc show no pronounced tendency toward it. The simultaneous application of stress to a metal under corrosion, as exemplified in the case of lead, is a powerful adjunct to deterioration by the development of intercrystalline brittleness.

Other cases of intercrystalline brittleness in metals were submitted to the Bureau for examination, and include the following: Duralumin sheet, used as "all-metal" airplane covering, and platinum crucibles containing a slight amount of tin.

Corrosion of Chromium Steels.

A study of a composition different from the "stainless steel" in common commercial use was undertaken. Nine alloys differing in carbon and chromium content were prepared by means of the electric induction furnace. These were pressed into plates, machined into cubical specimens, so that the surface area could be measured, and then subjected to corrosion in acid. The loss of weight per unit area per day will be used as a measure of the relative corrodibility of the different alloys. The corrosion tests are still in progress.

Distribution of Phosphorus in Low Carbon Steels.

This investigation, which was mentioned in last year's report, has been completed and the results summarized and submitted for publication as a technologic paper. The irregularity of microstructure as found in the steels after various heat treatments, and the presence of an unusual cellular-like structure within the individual grains as developed by etching, are attributed to the nonuniform distribution of the phosphorus, which varied in content within the limits 0.008 to 0.115 per cent. In general, the results confirm those obtained in the previous study of wrought iron of high phosphorus content.

Effect of Abrasion Upon the Hardness of Steel.

The hardening effect of abrasion upon steel is well known. In order to determine to what extent Brinell and scleroscope hardness, as well as microstructure of steels, are affected by rough treatment during the grinding processes a series of examinations was carried out. The results indicated that the hardening effect was confined almost entirely to a very thin surface layer, and that the Brinell and scleroscope hardness were not affected to an appreciable extent after rather rough treatment, such as excessive cuts by a surface grinder. Much of the hardening of steel by abrasion ordinarily observed appears to be the result of the heating by friction and the subsequent "quenching action" caused by the relatively cool metal of the interior of the piece.

Microphotographical Work.

The microscopy of metals involves considerable photographical work, since all permanent records are made in this way. During the year 3,047 micrographs have been made, 256 of which related to materials submitted for test, the remainder more in connection with the various investigations in progress.

Use of Etched Balls in the Brinnel Hardness Test.

At the request of the chairman of the committee on new hardness testing machines of the Engineering Division, National Research Council, a study based upon a suggestion which had previously been made to the committee concerning the use of etched balls in the Brinell hardness test was made. The ball ordinarily used for the Brinell test is made of chromium steel. The composition is such that even in the hardened state many microscopic particles of carbide exist throughout the material. These carbide particles are much harder than the matrix in which they are embedded. Slight etching of the surface is sufficient for exposing them, and when an indentation is made, as in the ordinary procedure of the Brinell hardness determination, each carbide particle produces its own indentation, so that the impression of the ball has a "matt finish." Such impressions are much more conspicuous on a polished surface of a hard steel than are similar ones made by an unetched ball. The method appears to be very useful for extremely hard steels, particularly if the surface has been polished. For softer materials there appears to be but slight advantage, if any, to be gained by etching the ball previous to use.

Proposed New Investigations.

In addition to the continuation of the various investigations now in progress as outlined above, the following proposed lines of new work for the coming year may be mentioned. In connection with the study of corrosion a further examination of zinc-coated products has been planned in cooperation with committee A–5 on the corrosion of iron and steel of the American Society for Testing Materials, with the ultimate aim of drawing up specifications for materials of this kind. Steel and iron differ in a pronounced manner among themselves in their resistance to atmospheric corrosion, according to the copper content of the metal. The difference in the protective oxide coating appears to be responsible, at least in part, for the difference observed in the rate of corrosion. An examination of the oxide coatings produced by atmospheric corrosion on various types of steels has been proposed.

In connection with a study of different types of welded rail joints, in which the Bureau has been requested to cooperate, considerable work on the structure of welded products will be necessary. This will include the various types of welding in industrial use, electric, hot-flame, and thermite welding.

THERMAL METALLURGY.

New Equipment.

An automatic temperature control for electric furnaces was obtained during the year, and in addition a number of furnaces, pyrometers, and auxiliary equipment formerly used in the heat treat-

ment of gauges were combined with the equipment of the heat-treatment section. Rearrangement of this equipment to provide adequate facilities for the hardening of high-speed tool steels, using single or double preheating methods, is now in progress. Experimental units for treatment of small samples in vacuum or definite atmospheres, such as hydrogen, nitrogen, etc., were also constructed.

Effect of Heat Treatment on Properties of Structural Steels.

Investigation of the effects of heat treatment on the properties of structural steels, with particular attention to the newer types of alloy steels for which special advantages have been claimed, has been continued. Some progress in testing the carbon-chromium and 3½ per cent nickel steels mentioned in last year's report and a carbon-uranium and high (air-hardening) nickel-chromium steel has been made, while in the following cases the studies undertaken have led to definite conclusions or have been completed:

One Per Cent Carbon Steel.—The tests originally planned for this steel have been completed. The effects of varying time-temperature relations in heat treatment on tensile and impact properties, hardness, and structure of 1 per cent carbon steel have been studied, including (*a*) effect of temperature variation in hardening, (*b*) time at hardening temperatures both above Acm and between Acl and Acm transformations, (*c*) effects of tempering steel hardened in different ways and effects of "soaking" just under the lower critical range, and (*d*) comparison of oil and water hardening for production of definite strengths.

Molybdenum Steels.—Tests were made of heat-treated carbon-molybdenum steel containing about 0.25 per cent carbon and 1 per cent molybdenum in an effort to correlate the mechanical properties with the "lowering" of the transformations. When quenched from relatively high temperatures within this "lowering range," better combinations of tensile strength and ductility and higher impact resistance were obtained than when hardened from lower temperatures. Similar experiments carried out on a widely recommended chromium-molybdenum steel containing about 0.30 per cent carbon, 0.90 per cent chromium, and 0.50 per cent molybdenum, show that the lowering of the transformations does not occur on slow cooling until temperatures much higher than those ordinarily used in hardening structural steels are reached. Following completion of these tests in the near future a publication will be prepared and, if possible, will be followed by experiments with other types of structural molybdenum steels.

Artificial Seasoning of Hardened Steels.

While it has not been possible to continue work on this investigation, reported under "Gauge steels" in 1920, available data have been summarized and a report prepared. The results of this work will shortly appear in technical journals.

Tensile Properties of Steels at High Temperatures.

Boiler Plate.—Based on a large number of tests made with a specially constructed apparatus as reported in 1920, a report was prepared entitled "Effect of Temperature, Deformation, and Rate

of Loading on the Tensile Properties of Low-Carbon Steel below the Thermal Critical Range." A summary of the work involved in its preparation is given in the following:

1. An apparatus was devised for studying the changes in tensile properties of metals at various temperatures, including determination of the limit of proportionality. A modified form of this equipment was also devised for studying the effects of variation in rapid rates of stress application on these properties.

2. Changes in tensile strength and ductility of several grades of boiler plate from 20 to 460° C. were determined. In addition, the effect of the following variables on the high-temperature properties of low-carbon steel was investigated: Cold rolling (tests on longitudinal and transverse samples), blue rolling (tests on longitudinal and transverse samples), tensional elastic overstrain, rate of loading (slow and rapid loading).

3. Partial annealing of cold and blue finished steel was also studied, and the final report includes selected bibliography on the mechanical properties of ferrous alloys at elevated temperatures.

Alloy Steels.—Comparison tensile tests of several structural alloy steels of acknowledged industrial importance and carbon steel of similar carbon contents at temperatures up to 550° C. were completed. The following were the type steels tested:

Steel type.	Composition (per cent).			
	C.	Ni.	Cr.	V.
A	0.38			
B	.38	3.5		
C	.38	3.0	1.0	
D	.38		1.0	0.20

While the request for this work originated in the Ordnance Department, because of trouble encountered in converters used in nitrogen fixation by the Haber process, the data obtained are of value in a wider field, including high-pressure steam installations, crude-oil distillation, etc. The chromium-vanadium steel was found to be the strongest of the alloys tested at 550° C., showing more than twice the strength and limit of proportionality of carbon and 3½ per cent nickel steels.

Thermal Analysis.

Autographic Method for Obtaining Inverse Heating and Cooling Curves.—The method of determining thermal transformations in metals, such as carbon and alloy steels, which has been the standard method in use at the Bureau for the past few years, requires more time for plotting the desired curves than to obtain the actual test data. An autographic attachment for present equipment was designed in order to make the routine determinations of thermal transformations more efficient and is now under construction. If successful in operation, it will be possible to make use of this equipment in metallurgical research as well, halving the time required for tests.

Magnetic Method of Determining Critical Ranges in Ferrous Alloys.—Magnetic methods of determining critical ranges have been widely used by Japanese investigators during the past few years in studying the constitution of alloy steels, and it has been intimated that such methods are better adapted to metallurgical investigations of this sort than the thermal methods more generally used. A simple apparatus was constructed for correlation of transformations determined by thermal and magnetic methods, preliminary to construction of more refined equipment for use in research work.

Iron-Carbon Alloys.—Publication of results obtained in determination of transformations of pure iron-carbon alloys fundamental in the heat treatment of steels has been delayed on account of the resignation of the staff member charged with the greater part of this work. This report will, however, be completed, it is expected, during the coming year.

Transformations in Alloy Steels.—Critical ranges of various alloy steels have also been determined from time to time as samples have been received. This work, which of necessity progresses slowly, will in time result in accumulation of valuable data.

Effect of Surrounding Atmosphere on Heat Treatment.

Annealing and hardening of low, medium, and high carbon steels in definite atmospheres was carried out. Preliminary tensile tests of steels so treated in hydrogen, nitrogen, and vacuum showed no changes in properties which could not be explained by differences in cooling rates or surface decarburization. However, hydrogen annealing of several brittle sheets supplied by one of the research associates resulted in a marked decrease in brittleness which was not again observed upon cold rolling. Upon completion of the preliminary tests now in progress further tests will be undertaken, providing such work appears warranted.

Heat Treatment of Carbon Steel.

This investigation was outlined in last year's report as an investigation being conducted in cooperation with the National Research Council in order to increase our present knowledge of the production of sorbite, both by determining the conditions of sorbitizing and determining the influence of the important variations of tensile and impact properties of the resulting sorbite. During the year progress has been made, although, because of the extended illness of the member of the staff working on this problem, no definite results can be given at this time.

Proposed New Investigations.

In addition to continuing work on the different investigations now in progress, as noted in several instances above, the following studies are planned for the coming year: (*a*) Continuation of tensile tests of alloy steels at high temperatures; (*b*) effect of varying heat treatments on the cutting efficiency (for various operations) of some tool steels in cooperation with the Structural Materials Division; (*c*) effect of several alloying elements on the properties of cast iron; (*d*) temperature variations in large masses during quench-

ing in commercial media and effect of size in heat treatment of given steels; (*e*) studies of the heat treatment of special structural alloy and high-speed steels.

MECHANICAL METALLURGY.

Effect of Rolling Conditions on the Properties of a Medium Carbon Steel.

This investigation, mentioned in last year's report, to determine the effects of certain rolling variables upon the properties of the finished product, has been nearly completed. The material used was an electric steel of 0.45 to 0.50 per cent carbon, of good homogeneity and soundness, thus eliminating as far as possible the consideration of the material as a variable.

The effect of the variables was determined by means of mechanical tests of rolled plates. Longitudinal and transverse tensile and impact tests were made on each plate rolled. At least two plates were rolled under each set of rolling conditions.

The results obtained indicate that the pass reduction has the greatest effect on the strength of the rolled material. The other factors are in this order, finishing temperature, initial temperature, and roll speed. None of these variables, however, have any marked effect upon the usual mechanical properties. At present certain of the results are being confirmed by additional tests and a few additional conditions are being studied. The results when completed will be published as a technologic paper.

Following this investigation it is hoped to make similar tests on other representative steels and nonferrous material and to compare the effects of rolling or forging of the same material.

Fish Scaling of Enamels.

In cooperation with the Ceramic Division some work has been done on the preparation of iron and steel sheets for enameling. Previous studies by the Ceramic Division indicated that stock which had been cold-worked was not as susceptible to "fish scaling" of the enamel coat as was similar material not so worked. Samples were prepared cold-worked in various manners, and after enameling substantiated the earlier results. It was also observed that a previous roughening of the stock, as with a fine corrugated roll, followed by cold rolling, further decreased the tendency to fish scale. The laboratory tests are being followed by similar tests on a larger scale in the steel mills and enameling plants.

Bearing Metals.

A technologic paper (No. 188) has been issued giving the results of tests at elevated temperature of five typical white-metal bearing alloys, four of which correspond to alloys specified by the Society of Automotive Engineers. The results of compression tests and Brinell hardness tests at temperatures up to 100° C. show that tin-base alloys maintain their properties better at elevated temperatures than the lead-containing alloys. It is also indicated that the addition of lead in amounts up to 5 per cent in a high-grade Babbitt does not affect the yield point or ultimate strength at 25 or 75° C. The yield point

of tin-base alloys is not affected by heating for six weeks at about 100° C., but the yield point is lowered in a lead-base alloy by heating for two weeks at about 100° C.

At the request of the nonferrous metals committee of the American Society for Testing Materials there is at present in progress a large number of tests intended to check and revise a table of properties accompanying the society's specifications for white-metal bearing alloys. These tests are being made upon the purest obtainable alloys, upon commercially pure alloys, and upon alloys made from secondary metals.

In addition to the work outlined above there is also planned for the coming year an investigation on the effect of rate of cooling during solidification on the properties of bearing metals and also further work on the standardization of wear and service tests.

Equilibria of Tin-Rich Ternary Alloys.

Some further work has been done on the study of the equilibria of the tin-rich ternary alloys of copper, lead, zinc, and antimony in all possible ternary combinations, up to a total of 1 per cent of each of the added elements. The primary purpose of this investigation is to obtain data which will aid in the interpretation of results obtained in routine testing of fusible boiler plugs, but it is also of considerable scientific interest. Freezing point determinations show that the effects of the added elements are neither individual nor additive. The results are now being assembled for publication, together with similar results obtained on the tin-rich binary alloys.

Strength of Solders and Soldered Joints.

An investigation has been started to determine the tensile strength of various grades of tin-lead, soft solders, and the effect of the common impurities upon the properties of such solders. Joints made with these solders upon many different metals and with various fluxes will also be studied in an endeavor to arrive at the best procedure for soldering given metal. The testing of soldered joints requires a means of readily making reproducible standard joints, and this phase of the problem is receiving first attention.

Fusible Metals for Helium Relief Valves.

In cooperation with the Engineering Physics Division a large number of fusible alloys have been prepared for investigation as to their suitability for the pressure-relief valves of helium containers. The melting range required of the alloy, together with the necessity of a sharp melting point while under pressure, are rather unfortunate from a metallurgical standpoint, and considerable difficulty has been encountered in preparing an alloy which would exactly meet the requirements.

Thermal Stresses in Chilled-Iron Car Wheels.

Although the experimental work on this investigation has been completed for some time, as noted last year, the publication of the results has been withheld pending an analysis of the data by the manufacturers of chilled-iron wheels. The results indicate that the maximum stresses developed are very close to the tensile strength

of the cast iron, and that this maximum stress occurs in the proximity of the junction of the double plates, at which place failure generally occurs in the tests conducted at the Bureau. It is expected that the data obtained will greatly assist the manufacturers and railroad engineers in improving the design of car wheels, particularly the larger wheels intended for severe service.

Graphitization of White and Gray Cast Iron.

This investigation is being undertaken at the request of manufacturers of chilled-iron car wheels to assist them in regulating their annealing-pit practice. Previous work had shown that the highest temperature at which no graphitization of the tread takes place under normal lengths of time is about 720° C. Continuing this work, samples of white and gray cast iron have been annealed at low temperatures (less than 700° C.) for various lengths of time up to 12 days. The experimental work is now completed and the results will shortly be published.

Thermal Stresses in Steel Car Wheels.

An investigation of the thermal stresses in steel car wheels resulting from brake action on long grades, similar to that carried out on chilled-iron wheels is in progress. A large number of rolled, forged, and cast-steel wheels, both new ones and those which have been in service, have been secured for test. So far none of the steel wheels have failed under conditions identical with those which gave rise to cracked plates in chilled-iron wheels.

Owing to difference in design of the steel wheels as compared with th chilled-iron wheels, the distribution of the thermal stresses is somewhat different in the two types. In the chilled-iron wheels it was found that the front of the wheel was all in tension. The tests on the steel wheels show that the front of the wheel is in compression near the tread and in tension near the hub. The stresses on the back of the steel wheels, which are negligible in the chilled-iron wheels, are now being studied. The steel wheels will also be subjected to higher tread temperatures in an endeavor to determine their ultimate capacity to resist thermal stresses as compared to the chilled-iron wheels.

Corrosion of Iron-Silicon Alloys.

The tests of acid-resisting alloys of the iron-silicon type, mentioned in the report of last year, have been continued. The work was considerably delayed owing to difficulty in securing a continuous steam supply during the mild winter just past. This difficulty has now been overcome by the use of individual steam baths for the hot tests, but since only a limited number of tests can be in progress at one time the entire procedure consumes considerable time. However, it is anticipated that during the coming year these tests, together with others on nonferrous acid-resisting alloys, may be reported.

Titanium Treated v. Untreated Rails.

This investigation is being carried out in cooperation with the Titanium Alloys Co. and the Illinois Central Railroad Co. and is a continuation of previous work done by the Bureau in studying various processes of manufacture of steel rails, with a view to de-

termining the proper methods of manufacture to insure sound rails. Samples from several heats of steel, with and without titanium, have been taken from the rails and are being surveyed for chemical homogeneity and soundness, uniformity of mechanical properties, microstructure, etc. The rails have been laid in portions of the track of the Illinois Central Railroad, where their performance will be closely watched.

Pure Platinum Wire.

Rolling and drawing equipment has been obtained for producing fine wire from the extremely pure platinum and platinum metals refined by the Chemistry Division. It has been found possible to draw these metals to quite small diameters without contaminating the original pure material. The equipment will be used for preparing standard thermocouple elements and material for studying the properties of platinum and platinum alloys.

Metal Specifications.

The Bureau is continually cooperating with Government departments and outside agencies in the formulation of specifications for metal products. Among those receiving such aid during the past year mention may be made of the Navy Department, War Department, Panama Canal, Library of Congress, Society of Automotive Engineers, American Society for Testing Materials, and the National Advisory Committee for Aeronautics. Many requests are received from outside parties for specifications for metallic products. Generally, existing specifications can be submitted, but in some cases new specifications are written to cover the request.

New Apparatus.

An instrument has been developed to measure the percentage elongation of broken tensile specimens, so as to eliminate the errors which are possible in the usual methods of measuring this factor. It consists essentially of a clamp to hold the specimen and two movable indices. When these indices are placed in the gauge marks, their relative position actuates a pointer over a dial which gives directly the percentage elongation. A paper describing the instrument is in press, in which data are given showing the results obtained in measuring elongation by various methods.

Continuation Work and New Work.

Mention has been made in the various items of the work which it is planned to continue during the coming year in this section. This includes the determination of the properties of metals as affected by various conditions of rolling, forging, or drawing; investigation of the properties of different grades of bearing metals, both at room and at elevated temperatures, in combination with the effect of pouring and casting conditions; a study of the strength of soldered joints and the proper combinations of solder and fluxes to be used for various metals; the corrosion of acid-resisting alloys; measurement of the thermal stresses in steel car wheels; a survey of rails made from steel treated with titanium and similar steel untreated.

A large number of new investigations are also planned, some of which are briefly described, as follows: It is planned to make determinations of the specific heat of metals up to and possibly above their melting points, and also of the latent heat of fusion. These data are of great value in metallurgical calculations, and for many of the metals the data at present available are not reliable.

It is expected that a study will be made of the hardness of the crystals of pure metals and of the microscopic constituents of alloys. It is hoped that this information will be of value in interpreting the properties of metals and alloys and of academic interest in considering the various theories regarding the structure of metals.

After careful standardization of the methods of making wear tests efforts will be made to conduct wear or service tests upon bearing metals. There is a continued call for such tests from the industry, but because of the large number of variables involved it is at present impossible to make tests of this kind which are satisfactory and truly comparable.

The Bureau's attention has recently been called to a large number of failures of car wheels occuring on one of the street car lines running into the District of Columbia. It is hoped to gather statistics on similar failures for all the car lines of the District and to determine the conditions which are responsible for the trouble encountered.

CHEMICAL METALLURGY.

Gases in Metals.

Method for Total Gas in Metals.—The method referred to in last year's report for determining the gases evolved from metals heated or fused in vacuum has been further developed and applied to steels and some nonferrous metals, particularly nickel, monel, and copper. It has been possible to eliminate the use of fragile and complicated mercury sample-collecting vacuum pumps, substituting therefor a simple mechanical vacuum pump. The metal sample to be tested is heated within an evacuated silica or glass tube, and the gases evolved are immediately drawn through a train of absorbents by the mechanical vacuum pump. Water and carbon dioxide are absorbed in tubes immediately following the vacuum furnace. The remaining gases are drawn through a furnace containing cupric oxide heated to 200° to 300° C., whereby hydrogen and carbon monoxide are oxidized to water and carbon dioxide and absorbed in the following tubes. Provision can also be made for burning and absorbing hydrocarbons when they are present by the use of a second copper oxide tube heated to a higher temperature. Nitrogen may be determined by absorption in metallic calcium vapor, as outlined in the direct method for nitrogen described below.

Tests with known gases and mixtures have shown the absorption or oxidation of water, carbon dioxide, hydrogen, carbon monoxide, and nitrogen to be fairly complete under the low pressures which exist in the absorbent train in this method. The high-frequency induction furnace is the most satisfactory means of heating the metal samples in this method, although for applications of the method in cases where only temperatures below 1,000° C. are required nichrome or chromel resistance furnaces are satisfactory.

A preliminary publication on this method is in preparation, describing the absorption train used and the application of the Ajax-Northrup induction furnace to the heating of the metal sample.

Direct Method for Nitrogen.—Further improvement and tests have been made on the direct method for the determination of nitrogen by absorption in metallic calcium vapor. Briefly, the method is as follows: A small piece of calcium is heated to 700° to 800° C. within a silica tube evacuated to a pressure of a few millimeters of mercury, an inner tube of iron keeping the calcium vapors from coming in contact with the silica. When the vaporization of the calcium begins, as indicated by a decrease in the pressure within the tube, the nitrogen or gas-containing nitrogen to be analyzed is admitted at a rate which does not allow the pressure within the tube to increase to any great extent. About 50 cubic centimeters of gas will be absorbed in three to five minutes. When the absorption is complete the furnace is cooled, the iron inner tube containing the calcium nitride and other oxidation products of the calcium is removed, and the contents of the tube dissolved in ammonia-free hydrochloric acid. The nitrogen in the calcium nitride is thus converted to ammonium chloride and is then readily determined by distillation from an alkaline solution, absorption in standard acid, and titration.

Analyses made on pure nitrogen have given a recovery of 99.5 to 99.9 per cent of the amount taken. The gas may be either dry or saturated with moisture. Mixtures of nitrogen with oxygen have given 99 to 99.8 per cent recovery; nitrogen with hydrogen, 99 to 99.9 per cent. With mixtures of nitrogen and carbon dioxide containing not over 10 per cent carbon dioxide the recovery of nitrogen has been 99.6 to 99.8 per cent, but with greater percentages of carbon dioxide in the mixture results have been low and erratic.

This method will be applied to the determination of nitrogen in the gas evolved from metals in the work on total gas in metals. The paper reporting the work is being prepared for publication.

Oxygen and Oxides in Steel.—Some applications of the Ledebur method for oxygen and microscopic methods for oxides in steel have been made in the course of the work, described under the heading "Deoxidizers and slags" below. The Ledebur method is also being used in conjunction with the work on total gas in metals and is an aid in the interpretation of the results obtained by the latter method.

Pure Metals and Alloys.

Electrolytic Iron.—During a large part of the past year two or three electrolytic baths have been running for the preparation of pure iron. A number of samples of this iron, either as deposited or after fusion in vacuum, have been supplied to Government laboratories and to educational institutions for use in various research problems. The larger part of this electrolytic iron has been used in the preparation of the pure iron alloys mentioned below.

Iron-carbon-manganese Alloys.—The preparation of this series of iron-carbon-manganese alloys was undertaken with the object of defining more exactly the rôle of manganese in steel. The carbon content of these alloys was varied in steps of 0.1 per cent from 0.0 to 1.5 per cent; the manganese in steps of 0.2 per cent from 0.5 to 1.2

per cent. The starting materials were pure iron (electrolytic), pure manganese, and an iron-carbon alloy (4.4 per cent carbon), prepared from electrolytic iron and pure carbon. All ingots were melted in vacuum in crucibles of magnesia very low in silica and sulphur. Ingots weighing 1½ to 2 kilograms thus prepared were rolled to flat bars. From these bars tensile test specimens were cut, two from each ingot, and a specimen for magnetic tests. Thermal analyses, microscopic examinations, and Brinell hardness tests were carried out on material from the broken tensile specimens.

The tests on the fully annealed samples of all ingots of this series have been completed. The paper giving the results of this work will be published early in the coming year. Work on the properties of alloys of some of these same compositions tested after various heat treatments is in progress.

Iron-carbon-manganese-sulphur Alloys.—A series similar to the preceding series of iron-carbon-manganese alloys, with the addition of sulphur in the steps 0.02, 0.04, 0.06, 0.08, and 0.10 per cent, is now in course of preparation. These alloys will be treated and tested in the same way as the iron-carbon-manganese alloys, and in addition their behavior on rolling and forging will be noted.

Pure Platinum Alloys.—The preparation of alloys of especially pure platinum with platinum group and other metals has been undertaken in cooperation with the Chemistry Division. Refractories have been tested as to their suitability for use in melting pure platinum without contamination, and a special high-frequency induction furnace coil has been obtained which is adapted to the melting of very small amounts of platinum by direct induction. Melts of pure platinum in vacuum have been made in this furnace.

Gold Alloys.—During the year five series of gold alloys were prepared for use as standards in the quantitative spectroscopic analysis of gold bullion for the United States mint.

The first three series prepared were gold-silver, gold-copper, and gold-iron alloys. Under each series there were three steps in the content of the metal alloyed with the gold, namely, 1, 0.10, and 0.01 per cent of either silver, copper, or iron, as the case might be. At a later date two more series of alloys were prepared from especially purified gold furnished by the United States mint. In these series several impurities were together added to the gold instead of one impurity at a time as in the first three series. Thus, the fourth series consisted of four melts of gold, containing, respectively, 1, 0.10, 0.01, and 0.001 per cent each of silver, copper, lead, and iron. The fifth series was prepared of the same steps in percentage of impurity, but with the omission of the iron.

These alloys were prepared in an induction furnace and, when necessary, under a stream of hydrogen to prevent oxidation of the alloying metal. The melts were either cast or hammered into rods 2 to 3 millimeters thick and 4 to 6 centimeters long, suitable for use as spark electrodes.

Refractories.

Magnesia Refractories.—Large quantities of magnesia low in silica have been prepared from Epsom salts and from basic magnesium carbonate. This pure magnesia has been used in the preparation of

crucibles and linings for carbon crucibles, in which many of the pure metals and alloys prepared in this section have been melted. Light calcined magnesia and aluminum oxide have been used as binders for the heavily calcined magnesia in the preparation of crucibles. Recently it has been found that the addition of from 1 to 8 per cent of magnesia fluoride serves more satisfactorily as the binding agent.

Special Refractories.—Considerable experience with special refractories has resulted from some of the alloy and electric furnace work of this section, particularly as related to crucibles and radiation screens used in the work on gases in metals and crucibles for melting platinum, gold alloys. titanium, and ferroalloys.

Small experimental crucibles for special work have been made from pure aluminum oxide, pure lime, mixtures of zirkite-magnesia or zircon-magnesia, zircon-lined graphite crucibles, crucibles of compressed pure tungsten powder, and powdered ferrotungsten. Small lots of magnesia and of lime have been electrically fused for use in the preparation of special refractory shapes.

The crucibles of compressed tungsten powder have been found very useful in connection with the high-frequency induction furnace. Such crucibles heat very rapidly and efficiently and can be used to heat to very high temperatures small quantities of materials which heat with difficulty or not at all by direct induction.

Zircon-lined graphite crucibles have been used with some success in electric furnaces when the atmosphere is oxidizing.

The section has endeavored to keep in touch with the commercial developments of metallurgical refractories, and especially the less common refractories for special uses at very high temperatures.

Chemical Metallurgy Standards.

Ladle-Test Ingot Investigation.—In accordance with the program of the committee of the American Society for Testing Materials which is handling this investigation, test ingots have been obtained during the year from nine cooperating steel companies. Two sets of test ingots were taken by each company from each of several open-hearth heats of steels of low, medium, and high carbon contents. These test ingots were taken by the company's regular practice in one case and by the committee's specified practice in the other. The latter practice modified the company's methods only by the addition of aluminum to the mold before the ingot is poured. The purpose of this work is to ascertain (1) whether the aluminum addition eliminates blowholes in all the types of ingot tested, and (2) whether the aluminum-treated ingots are more homogeneous chemically.

The entire set of ingots has been received at the Bureau, split longitudinally, so as to facilitate the Bureau's examination. The aluminum ingots are invariably sounder and freer from blowholes, regardless of ingot type or pouring practice.

The Bureau is now drilling the ingots at three widely separated places on the split faces, and the drillings are to be analyzed for carbon, sulphur, and phosphorus, in order to get comparative results for chemical uniformity on the aluminum and nonaluminum treated ingots.

Invar (36 Per Cent Nickel Steel).

Some work has been undertaken on the preparation and working of invar (36 per cent nickel steel), with the object of determining the influence on the properties (thermal expansion, aging, etc.) of the small amounts of impurities present in the commercial alloy.

A number of ingots have been prepared using ingot iron, or electrolytic iron, and shot-nickel, or electrolytic nickel. Ingots have thus far been made with carbon content fixed, but with different deoxidizers (manganese, silicon, aluminum) added in varying amounts. Several of these ingots have been forged and specimens prepared for chemical and expansion tests.

New Equipment.

The transformer capacity for the operation of Arsem furnaces has been doubled by the installation of a new 25-kva transformer and switchboard giving any voltage from 1 to 61 in 1-volt steps. This is a duplicate of the previous equipment and makes available for electric-furnace operation 50 kva at any voltage from 1 to 61.

A new 20-kilowatt high-frequency converter for the operation of an Ajax-Northrup induction furnace has been installed. This new equipment will be used for the preparation of alloys, castings in chill or sand molds, and for miscellaneous melting and high-temperature work, thus allowing the use of the smaller (10-kilowatt) converter and furnace exclusively on the problem of gases in metals.

A cabinet sand blast has been purchased and recently installed.

Proposed Work.

Special attention during the coming year will be given to the work on gases in metals and the application of the method of analysis that has been developed for total gas in a metal, to steels and nonferrous metals which have been manufactured by variations in commercial practice. The lack of definite knowledge of the effects of gases in metals and of the most efficient methods of control of gas content is at present the cause of very serious wastes of materials, time, and labor in almost all metallurgical work.

The work on the properties of alloys of pure (electrolytic) iron with additions of carefully controlled amounts of impurities will be continued. The next phase of this work (already undertaken) is the investigation of the effect of sulphur on such alloys. This work will correlate with the program of the joint committee on sulphur and phosphorous in steel which is doing its work in steel mills on a commercial scale.

It is desired to continue more actively the work on special metallurgical refractories, by service tests of some of the newer electric furnace refractories, and small-scale tests of refractories for very high temperatures. At present the available personnel permits only intermittent attention to the work.

The work outlined above under pure platinum alloys should also be given special attention during the coming year.

EXPERIMENTAL FOUNDRY.

Experimental and Practical Castings.

The foundry has continued during the past year to serve the Bureau, research laboratories, and Government departments in the making of metal and alloy castings. There was an increase over the previous year from a total of 1,946 castings from 401 patterns to a total of 2,358 castings from 459 patterns. The total estimated value of castings made during the year is $2,710.

Molding-Sand Investigation.

During the past year an extensive investigation of 10 different sands submitted by the State Geologist of Georgia has been carried out, the results of which showed that these sands were not natural molding sands because of their excess of clay. This difficulty, however, was overcome by lessening the amount of water used in the initial experiments to 10 per cent, making it possible to use any of them as molding sands. Their uniformly high melting points and favorable grain size made them all of practical value provided they were properly tempered for molding purposes.

There is in preparation a circular on foundry tests of molding sands which it is expected will give descriptions of the more important methods of tests and those in use at the Bureau.

Weathering of Art Bronzes.

As was stated in last year's report, this investigation is being carried out in cooperation with one of the statuary manufacturers to determine the relation of the composition of statuary bronzes to the facilities with which they assume patinas upon exposure to weather. The specimens have been exposed to the weather since August, 1916, and it is planned to continue their exposure until 1926. The various specimens now show to a slight extent the color of the patina which they may be expected to assume.

Government Bronze and Its Substitutes.

Owing to limited personnel the investigation of the influence of small amounts of Al, Sb, and Ni added to alloys of 88 Cu, 10 Sn, 2 Zn, and 88 Cu, 8 Sn, 4 Zn has not progressed as far as was expected during the last year. It is proposed to include the effect of the addition of small amounts of iron (from 0.10 to 1 per cent iron). In one set of experiments the iron is to be added by means of zinc dross, which contains a limited amount of iron, and in the second set it is to be added in the form of ferrous oxide. This series of tests is to be accompanied by photomicrographic studies of the broken test bars.

In addition it is expected that a series of tests will be conducted in which nickel is to be added in the form of a nickel-tin hardener which has already been prepared. This method it is hoped will result in an improvement of the physical properties of the alloys.

ITEMS OF MILITARY INTEREST.

Erosion of Machine-Gun Barrels.

About 20 steels for this investigation, recommended by the Bureau to the Ordnance Department, have been prepared. These steels were selected because of their forgeability, machineability and possible

resistance to erosion. During the year such data as were desirable in connection with the physical properties of these steels have been collected, the manufacture of the barrels and the firing tests being conducted at Springfield Armory. The results of the tests to date have demonstrated that several steels may prove to be superior to the type of steel now being used in general production. Of the total of 20 steels prepared, 3 have indicated their superiority to the ordinary machine-gun steel, 6 their ability to equal the ordinary machine-gun steel, and 2 have been entirely eliminated as unfit, and the remainder are probably inferior to the ordinary machine-gun steel.

At present confirmatory firing tests in duplicate are being made on the steels not yet eliminated and should be completed during the next year.

Efforts to electroplate gun barrels have not been successful, a report of which work is now in progress. Reports have already been submitted on the effect of poor cooling upon the life of gun barrels, on the causes leading to bore enlargements, and on the relation between the tensile properties of the steel and the accuracy life of the gun barrel.

Corrosion of Metals by Ammonia Gases.

The War Department, through the fixed nitrogen research laboratory, is interested in obtaining metals capable of resisting corrosion by gases at high temperatures and pressures. Interest is manifest in the mechanism of deterioration, rate of deterioration, loss in tensile properties, permeability to gases, and endurance of metals suitable for service in the fixation process. A total of 30 alloys is being investigated, 25 of which are steels and 5 nonferrous alloys. The work so far has progressed to the point where the record of physical properties, such as structure, strength, and thermal behavior, has been completed.

Development of Light Armor Plate.

A research has just been begun on the development of light armor plate. This work requires the rolling, casehardening, and heat-treating of a number of special steels. Firing tests of the finished plate are to be made at one of the Army ordnance proving grounds. This research is a part of a larger program undertaken by the Ordnance Department. The Bureau expects to determine the efficiency of different commercial carburizers in addition to determining the susceptibility of the different steels to carburization.

Tensile Fractures of Gun Steels.

A metallographic investigation of the relation between certain types of fractures and the structure of common steels has been completed, and the work it is expected will be compiled into a summary of the findings and a classification of the various fractures into groups or basic types.

Armor-Piercing Bullet Cores.

A study of a number of different types of armor-piercing bullet cores was completed some months ago. The problem involved the study of several steels differing in composition. A number of heat

treatments were applied to each steel and tests were made of those physical properties which are most desirable in armor-piercing bullet cores. The research succeeded in determining the relative fitness of the different steels for armor-piercing ammunition. The net results eliminated approximately six of a total of nine types of cores and concentrated design development upon those types remaining.

Miscellaneous Tests for Ordnance.

Among the several special examinations made for the Ordnance Department on materials which had failed in service or had been submitted as articles of merit may be mentioned anticorrosion alloys, platings, alloy steels, bullet cores, tractor parts, tank armor, light armor, gun metal and nonferrous alloys.

Manufacture and Properties of Steel Plates for Light Armor.

This investigation originated from the need of the Ordnance Department of the Army and the Bureau of Ordnance of the Navy for information regarding the effect on the ballistic properties of light armor plate of certain chemical elements, such as zirconium. It was carried out in cooperation with the Bureau of Mines and the Navy Department.

Although the results on the ballistic properties are not available for publication, an account of the mechanical properties and tests of this series of somewhat unusual steels was considered of interest, and a publication dealing with these data is now in press.

About 193 heats of steel, prepared by the Bureau of Mines, containing in various combinations the following elements, carbon, silicon, cobalt, boron, copper, cerium, molybdenum, chromium, uranium, and tungsten, have been studied. None of these steels presented any difficulties in rolling into plates, except those containing boron. Boron forms a complex eutectic, probably that of an iron-carbon-boron compound with iron. This eutectic is fusible at the temperatures ordinarily used in rolling, but at lower temperatures steel containing boron can be rolled successfully.

The usual mechanical properties and impact tests were carried out on all the steels. It was shown that steel containing 0.4 to 0.5 per cent carbon, 1 to 1.5 per cent silicon, 3 to 3.25 per cent nickel, and 0.6 to 0.8 per cent manganese and deoxidized with a simple deoxidizer such as aluminum can be produced, having a tensile strength of approximately 300,000 pounds per square inch, with excellent ductility and toughness. This type of steel is recommended as a structural material for special purposes.

German Motor-Truck Parts.

As part of a study of the materials used in captured German motor trucks requested by the Motor Transport Corps, a large number of ball bearings were examined. The composition and the hardness of the balls and races are practically identical with similar material made in this country, a carbon chromium steel being used.

Precision Altimeter.

Following the precision altimeter which was constructed last year two additional instruments of different design have been constructed in cooperation with the aeronautical instrument section. The suc-

cess of these instruments is largely due to the attention given to the material and treatment of the steel springs employed. A paper describing the necessary precautions to be observed is now in press.

RESEARCH ASSOCIATES.

There have been stationed at the Bureau during the past year six research associates and assistants in metallurgy, representing industries or organizations which desired to take advantage of the facilities of the Bureau for the prosecution of investigations in which both the industry as a whole and the Bureau were interested. This plan has worked excellently and could well be taken advantage of by other industrial organizations. The following paragraphs give an account of the progress of work of these associates during the year.

Iron in Brass.

The problem of quantitatively determining magnetically small amounts of iron in brass resolved itself into a study of the magnetic properties of brass containing small percentages of iron. The specimens used were cast-brass rods about 13 millimeters in diameter and 12 centimeters long, turned down to size and with a composition of copper 82 per cent, tin 3 per cent, and zinc 15 per cent. The amount of iron in the specimens varied from 0.01 to 0.8 per cent. Magnetic tests indicated that the individual bars were uniform in properties, while preliminary microscopic examination showed that up to a certain amount the iron had completely dissolved in the brass in each case. The method consisted in connecting up two mutual inductances in such a way that their electromotive forces were equal and balanced each other when no specimen was present. When a sample was introduced in one coil, however, and not in the other, the galvanometer gave a deflection that was proportional to the susceptibility of the specimen. By this means magnetic susceptibilities as low as 4×10^{-6} could be measured. From the results obtained in these first measurements the magnetic properties apparently do not bear any very definite relation to the per cent of iron in the brass. The effect of work on the magnetic properties of these specimens, it is expected, will also be studied.

Sherardizing.

For this investigation it was found necessary to construct a rotating, wire-wound electric furnace which was so built that the part of the heat chamber used did not vary more than 3° C. in temperature. Also the effect of the variables, time and temperature, on sherardizing was studied. Samples of iron low in carbon and with few impurities were sherardized at 340°, 370°, 400°, and 430° C. for three hours and also for one, three, and six hours at 370° C. The coated samples, the gain in weight of which had been noted, were tested by stripping in antimony chloride solution, exposing to salt spray, tumbling in a ball mill, and microscopic examination. The gain in weight during sherardizing gave the amount of zinc deposited and the loss in weight by stripping measured the total weight of the coating. The difference between the two gave the amount of iron alloyed with the deposited zinc.

The data collected so far, it is thought, are not extensive enough to warrant definite conclusions. It is expected to continue the sherardizing investigation by studying the addition to the base metal of various amounts of silicon, manganese, phosphorus, combined carbon, and graphitic carbon, and its effect on the sherardized coatings produced, also the influence of the metallic content of the zinc dust and the rate of rotation during sherardizing.

Researches on Monel Metal.

Alternating stress tests on monel metal which have been done thus far indicate that hot-rolled monel metal will stand at least 75,000,000 alternations of stress of 38,000 pounds per square inch. A paper including the results of these tests was presented before the June meeting of the American Society for Testing Materials.

The results of tests on monel metal with a Charpy impact testing machine have been prepared in the form of a paper, which gives the average of 10 tests as 160 foot-pounds. Tests to determine the impact values with an Izod machine were not satisfactory, as the monel-metal specimens did not fracture.

Tests on the melting range of monel metal were found to vary slightly with the composition. The highest range observed was 1,315° to 1,351° C., while the lowest was 1,284° to 1,319° C.

An investigation is in progress to determine the character and quantity of gas in monel metal with the object of devising methods of elimination.

Study of Nickel.

Tests have shown that pure nickel melted in an atmosphere of hydrogen and solidified in vacuo is malleable and may be worked into shape for the determination of its physical properties. Specimens are now being prepared for the determination of the properties of exceptionally pure nickel furnished by the research department of the International Nickel Co. The density of pure nickel cast in vacuo was found to be 8.889 g/cc. at 25° C.

Experimental work on the equilibria of nickel-nickel oxide is in progress. Unsuccessful attempts have been made to obtain the solidus of nickel containing small amounts of nickel oxide. It is believed that the Bureau now has apparatus and a method which will be suitable.

Deoxidizers and Slags.

During the year a paper was published in Chemical and Metallurgical Engineering (Nov. 3, 1920) giving the results of the first phase of this investigation. The purpose of this first investigation was to make a preliminary survey of probable deoxidizing alloys containing varying amounts of manganese, silicon, titanium, and aluminum.

The fundamental assumption of the experimental method used was that the action of desirable deoxidizers should produce deoxidation slags (oxides of the elements in the deoxidized alloy) fusing below the melting point of steel, the idea being that such fusible slags would most readily separate from the molten metal, thus freeing it from foreign inclusions. Accordingly, 120 mixtures of oxides

of manganese, silicon, titanium, and aluminum were made up and the melting points of these mixtures determined. All oxide mixtures melting above 1,500° C. were excluded from further consideration. From the oxide mixtures melting below 1,500° C. the percentage composition of the alloys corresponding to the oxides was calculated.

As a result of this work 73 possible deoxidizing alloys were computed from the determinations of oxide melting points. Nearly all of these would give deoxidation slags melting well below the melting point of steel. The other 47 combinations were excluded from further investigation. It was shown by this work that titanium oxide was very effective, not only lowering melting points of such mixtures, but also in conferring greater fluidity on the deoxidation slags.

The next phase of the work was to make some of the deoxidizing alloys, devised as a result of the work above described. In planning this work it was decided to confine attention at first, as far as possible, to low-carbon alloys, since it is known that the presence of carbon in some deoxidizing alloys introduces complications by the formation of carbides with the active elements of the deoxidizer and by the deoxidizing action of carbon itself. No attempt was made to produce all the 73 alloys mentioned above, as they were represented by several groups, and there usually was little difference in the slag-melting points of such group members.

The majority of these alloys made up have been tested to some extent for deoxidation of steel or commercially pure iron, but the results obtained are considered far too incomplete to justify any conclusions at this time as to their relative efficiency for deoxidation. Such conclusions must await completion of a considerable amount of experimental work, a program of which it is now possible to outline from the previous work, as follows: (1) Removal of iron oxide, (2) removal of blowholes (gases), (3) production of sound ingots, homogeneous chemically and physically, and with minimum amount of "pipe," and (4) production of metal that will not break up on forging; i. e., metal free from solid inclusions and from sulphur red-shortness. Work along the above lines is in progress, and the following may be stated tentatively as the result of experimental deoxidations thus far conducted:

The fundamental assumption underlying the first phase of the deoxidizer investigation, namely, that deoxidizers giving deoxidation slags fusing above the melting point of iron are undesirable, has been confirmed. Deoxidations were made with 95 per cent silicon, 98 per cent aluminum, and with 75 per cent manganese. In all these cases the deoxidized iron broke up on forging and showed a large amount of inclusions.

It has been shown that some of the combinations of manganese with silicon and titanium are very effective in cleansing the iron from solid inclusions—at least so far as the small-scale tests indicate.

It has been found possible on the small scale with some of the latter deoxidizers to reduce the Ledebur oxygen content of the "standard" oxygenized iron from the original 0.06 per cent to an amount not determinable by the method.

There are indications that magnesium, calcium, and lead when properly alloyed can be of use for deoxidation of ferrous materials.

Effect of Different Elements on Red-Shortness of Iron.

Considerable work has been done in studying the effect of different elements on the red-shortness (brittleness when worked hot) of commercially pure iron and electrolytic iron. The following phases of the work have been studied in some detail, and the results are to appear later as a technical publication: (*a*) Effect of small amounts of sulphur on the red-shortness of electrolytic iron and of ingot iron; (*b*) quantitative study of effect of manganese in eliminating the sulphur red-shortness; (*c*) effect of oxygen on red-shortness of electrolytic iron where less than 0.01 per cent sulphur is present: (*d*) effect of copper on red-shortness of iron containing minimum amounts of sulphur and oxygen and practically manganese free (electrolytic iron).

GENERAL ACTIVITIES.

Tests.

Tests Involving the Microscopy of Metals.—The tests and examinations involving the microscopy of metals are nearly always of an investigational character rather than routine. Considerable research work is often required; an interpretation of the results of the microscopic observations and the application of them to the particular case under observation are always necessary. Often recommendations, particularly in the case of examination of metals which failed in service, are requested. In many cases other lines of testing, such as determination of some of the mechanical properties, are necessary.

The following tests are cited as typical of examinations which the division is often asked to make. Many of the requests for such examinations are received from manufacturers and other industrial sources.

Embrittled Duralumin.—This alloy is used extensively in aeronautical construction. The material examined was in the form of thin sheets used as covering on an "all-metal" plane. After a relatively short service life the sheets showed areas in which the metal had become so brittle that it would crumble in the fingers. The deterioration consists in an intercrystalline attack by which the "bond" between adjacent crystals is destroyed, although the body of the crystal is not appreciably affected. Corrosion appears to be one of the fundamental factors by which such embrittlement is produced. Other causes for this condition will be sought.

Brittle Platinum.—A somewhat similar case of embrittlement was observed in a platinum crucible submitted to the Bureau for examination. Analysis showed that the material contained a small amount of tin. This exists in the platinum as a compound of the two metals in the form of films enveloping the grains to a large extent, and thus accounts for the brittleness of this platinum.

Nickel Anodes.—Anodes for use as a source of nickel in electroplating should contain a considerable amount of graphitic carbon. It not only aids in the casting of the anodes, but permits them to corrode much more uniformly than is the case when the carbon content is low. The examination of several typical anodes showed that the unsatisfactory behavior of those low in carbon was apparently the result of intercrystalline films, presumably of an oxide nature. The dissolving of this film allows crystals of the metal to be removed

bodily, thus adding to the amount of "sludge" and to the roughness of the deposit.

Brazed Joints for Sheet Copper.—An examination of different types of brazed joints showed a simple "lap" joint to be superior in mechanical strength and structure to a "lock" joint. The longer period of heating which the latter type requires for causing the "braze" to penetrate the joint often overheats and burns the top fold of the "lock" so that inferior properties result. The adjacent metal of the sheet is also much more apt to be affected than is the case with the simpler joint.

Antique Armor.—Several specimens of fifteenth century chain and mail armor were examined for the Metropolitan Museum of Art. The examination indicated that the steel was made by a process very similar to that used at present for wrought iron. The material was afterwards carburized, hammered into shape, and often plates of different hardness were welded together so as to present a hard outer surface and softer backing. The material was finally quenched in order to harden it.

Oxyacetylene Cutting of Steel.—Two important features examined in connection with this process were the surface hardening, which nearly always occurs, and the production of cracks in such pieces. The process of surface hardening by the "quenching action" of the relatively cool interior upon the hot surface has been patented and is used successfully in hardening the surface of many small complex shapes which, because of their shape, would not stand the ordinary quenching. The cracks resulting from oxyacetylene cutting appear to be found more frequently in large sections than in small pieces. The character of the steel also appears to play a part.

Graphitization in Steel.—The examination of some high-carbon steel (tool steel) submitted showed that the material had been spoiled in annealing, so that approximately 0.5 per cent of graphite was present. This, of course, rendered the steel unfit for any purpose for which tool steel is used.

Welded Steel Tubes.—The fact was brought out by the examination of specimens of welded steel tubes that for satisfactory behavior in the welding machine a steel of low carbon and sulphur content was desirable. Steel of a somewhat higher content of these two elements, also containing considerable slag, gave very unsatisfactory welds under the same conditions.

Duplex Metal Sheets.—Several examples of sheets of German origin in which the outer layers were of either copper or nickel firmly welded (by rolling) to the steel base were examined. The sheets are prepared by rolling the required number of billets superimposed one upon the other. It is necessary that they be protected in a suitable manner during the necessary preliminary heating. Bullet jackets consisting of a soft steel base with thin outer coatings of cupronickel prepared in this manner were used during the recent war by the German forces.

Wrought Iron.—One of the best criteria to use in deciding whether a product should be classed as steel or as wrought iron is the examination of the structure. Numerous specimens have been submitted for this examination.

Locomotive Crank Pin.—The examination of a locomotive crank pin, the failure of which was the cause of a railroad wreck, showed

that the material had failed by "fatigue." The material complied in its mechanical properties with the specifications under which it was purchased. It was shown, however, that by a very simple heat treatment the elastic properties of the steel could be very materially improved without a corresponding decrease in ductility, and also that the structure of the steel would be put into the best condition possible. This would serve to lengthen the life of the crank pin very materially when subjected to "fatigue stresses."

Steel from a Condemned Marine Furnace.—The material was submitted by the Steamboat-Inspection Service for the purpose of obtaining evidence as to whether or not the inspector was justified in condemning the furnace. The examination revealed numerous fissures which had developed on the "waterside" in certain portions of the boiler. The tensile properties of the steel had not yet been seriously affected, although other tests, particularly cold-bending, showed that the material had been materially affected in its properties. The production of the "fissures" was progressive in character, so that it appeared to be impossible to say when they had progressed to such an extent as would render the material entirely unfit for use. The results of the examination, on the whole, justified the inspector in the action taken.

Satisfactory Materials.—It sometimes happens that a metallographic examination reveals the fact that the material is entirely satisfactory, in which case it is evident that the cause of the unsatisfactory service must be sought elsewhere, usually in operating conditions. Materials submitted illustrating this point were boiler tubes showing peculiar corrosion pits and a cast-iron boiler section which developed cracks in service.

Working of Metals.—The rolling and forging equipment of the Bureau is quite often called upon to produce material for various sections of the Bureau and other Government departments. Among the work of this character performed during the past year the following may be mentioned: Forging of nickel, forging of invar, cold rolling several hundred small sheets of steel for paint tests which could not previously be readily pickled, rolling spring steel, rolling very thin material as phosphor bronze, manganin, aluminum, etc., rolling experimental alloy sheets for the Navy Department.

Fusible Boiler Plugs.—There were tested during the year 578 fusible boiler plugs, 546 being tested for the Steamboat-Inspection Service, 23 for the Panama Canal, and 9 for the Interstate Commerce Commission. Of these, 140 were rejected, 72 on account of the copper content being more than 0.3 per cent, 48 on account of the copper content being more than 0.3 per cent and the lead content more than 0.1 per cent, 14 on account of the lead content being more than 0.1 per cent, 2 on account of copper content being more than 0.3 per cent and the zinc content being more than 0.1 per cent, 2 on account of iron content being more than 0.1 per cent, 1 on account of the antimony content being more than 0.1 per cent, 1 on account of the casing not being bronze, and 3 on account of failures in mechanical specifications. Eleven plugs were reported as having loose fillings.

Miscellaneous Tests.—During the year miscellaneous tests have been made upon bearing metals submitted by manufacturers, also a

bearing grinding compound, knitting-machine needles, aluminum solders, cast aluminum alloys, special process treated steel, transverse tests on cast iron, wear tests on carbon and molybdenum steels, soldering fluxes, and brazed copper sheets.

Table of Tests.—In the past year a great variety of tests were made of various metals and alloys for other sections of the Bureau, Governmental departments, and the public. As shown by the accompanying table, there was a total of 5,588 tests, the estimated value for the total number being $16,690.

Tests completed during fiscal year 1921.

	Heat treatment and thermal analysis.		Metallographic (including physical, chemical, and corrosion tests).				Fusible plugs.	Castings.		Total.
	Irons and steels.	Non-ferrous metals.	Irons and steels.	Aluminum alloys.	Brass and bronze.	Miscellaneous.		Ferrous.	Non-ferrous.	
For the Government:										
Commission lighthouses			2							2
Foreign and Domestic Commerce						1				1
Bureau of Standards	1,852	50	158	2	7	54		168	1,769	4,060
Navy Department	5									5
Panama Canal			10			1	23			34
Steamboat-Inspection Service			4				546			550
War Department	375		5		2				12	394
Post Office Department			1							1
Interstate Commerce Commission			1							1
Coast and Geodetic Survey									405	405
Treasury Department			1							1
National Advisory Committee for Aeronautics									4	4
U. S. Railroad Administration			38							38
Congressional Library				1	3					4
Total	2,232	50	220	3	12	56	569	168	2,190	5,500
For the public	14	1	67	2		4				88
Grand total	2,246	51	287	5	12	60	569	168	2,190	5,588

Circulars of Information.

The Structure and Related Properties of Metals.—During the past year a circular bearing the above title and summarizing the Bureau's experience in the study of the structure of metals has been prepared. The circular is a comprehensive one, and such features as methods for revealing structure of metals, conditions affecting structure, effects of structure upon properties, and applications of the microscopy of metals are discussed in detail and illustrated by means of numerous references to materials which have been submitted at different times to the Bureau for examination and test. The "practical" application of the microscopy of metals has been constantly kept in mind, and it is anticipated that the circular will serve a very useful purpose in answering many of the numerous requests for information along this line which are received.

Metallographic Testing.—The circular describing the different lines of investigation and tests for which the Metallurgical Division

is equipped has been revised and enlarged. The circular has been submitted for publication and will soon be available for distribution.

Nickel.—The circular on nickel (No. 100) has been issued during the past year. This circular includes information concerning the manufacture, chemistry, metallurgy, and physical properties of nickel and some of its alloys.

Cooperation with Technical and Scientific Organizations.

The Metallurgical Division has continued, through committee memberships of various members of its staff, active cooperation with various scientific and technical societies and groups interested in metallurgy. Among these groups which are carrying on active research may be mentioned the various committees of the American Society for Testing Materials, the Joint Committee on the Investigation of Sulphur and Phosphorus in Steel, the Committee Advisory to the Bureau on Nonferrous Alloys, National Research Council, and Engineering Standards Committee. There is in formation a committee on iron and steel representative of these industries. There is also in formation a committee for the investigation of welding under street-railway conditions. The formation of a research group is contemplated to study in a comprehensive and systematic manner the various fundamental and practical aspects of the corrosion problem. Preparations are being made for the editing of a critical table of physical-chemical constants on the advisory board of which the Bureau is represented by the chief of the Metallurgical Division.

Committee on Sulphur and Phosphorus in Steel.—The steel manufacturers, on the one hand, as represented by the Association of American Steel Manufacturers, and the specification-making bodies, on the other, such as the United States Railroad Administration and the American Society for Testing Materials, as well as the Bureau of Standards, have recognized for some time the urgent necessity of revision of the requirements as to the content of sulphur and phosphorus in various grades of steel. The present specifications are largely a matter of tradition and based on fuel and ore conditions which existed several decades ago. In view of the questions of life hazard involved in the use of steels for various purposes, the specification-making bodies are loathe to change the sulphur and phosphorus requirements without further experimental evidence.

There was, therefore, formed on June 23, 1919, a joint committee for the investigation of sulphur and phosphorus in steel with the Bureau of Standards (Dr. George K. Burgess as chairman), and made up of representatives from the Railroad Administration (replaced by the American Railway Association), War Department, Navy Department, American Society for Testing Materials, Society of Automotive Engineers, Society of Naval Architects and Marine Engineers, National Research Council, Association of American Steel Manufacturers, Steel Founders' Association of America, and American Foundryman's Association. A systematic program of investigation has been laid out and excellent progress has been made in its execution, involving very extensive work in the Government laboratories at Annapolis experiment station, Watertown Arsenal, and the Bureau of Standards, as well as extended service tests, and the most

hearty cooperation on the part of the steel manufacturers who are furnishing the material under the supervision of the joint committee. The manufacturers have already spent several thousand dollars in producing material for the committee, and the expense of testing is being borne by the several Government laboratories and institutions.

Committee Memberships.

The metallurgical division cooperates with various committees as follows: The National Advisory Committee for Aeronautics, National Research Council, American Institute of Mining and Metallurgical Engineers, American Society for Testing Materials, Joint Committee on Sulphur and Phosphorus in Steel, American Physical Society, Engineering Standards Committee, Society of Automotive Engineers, American Society for Steel Treating, Reclassification Committee, and with the Advisory Committee on the Critical Table of Constants.

Exhibit.

There was shown at the Convention of the American Steel Treaters' Society the week of September 14, 1920, an exhibit illustrative of the various lines of metallurgical work in which the Bureau is actively engaged, the exhibit consisting of the work of the several sections of the division, which was shown by means of photographs, typical specimens, and apparatus.

Conferences.

There have been held at the Bureau during the past year two semiannual meeting of the advisory committee on nonferrous alloys, on November 10 and April 20, respectively. Among the subjects discussed are the following: Specifications for hard-drawn brass wire, modifications of a mercurous nitrate test, cadmium plating, standard chemical samples, bearing metals and solders, casting light alloys on to steel, material for annular safety release for high-pressure containers, aluminum alloys for all metal airplane covering, molding sands, improvement in refractories, gases in metals, corrosion, variations of 88–10–2, expansion, spectral analysis, fatigue, and magnetic properties.

A conference was held with respresentatives of the manufacturers of chilled-iron car wheels at which the results of the Bureau's investigation of thermal stresses in chilled-iron wheels were discussed. The manufacturers are much interested in this work, which they believe will assist them in improving the quality of chilled-iron wheels and in indicating where the design may be improved. They requested that the publication of the results be withheld until they have had time for their further analysis.

Correspondence and Travel.

During the year members of the metallurgical staff have had opportunity to attend various conferences on technical and scientific subjects.

Illustrative of the varied requests for information on technical and scientific subjects there is given below a list of topics of correspondence for the month of June, 1921: Specifications for S. A. E.

bronzes, process of babbitting boxes, seasoning of steels, commercial grades of Monel metal, yield point of Monel, hardening copper, standard shrinkage test for cast iron, disapore brick, standard method of sampling pure aluminum, manufacture of 18 B. and S. solder, steel for saw frames, breakage and heat treatment of rock drill steels, Government bronze, tempering of aluminum, stopper brick, duralumin, X rays in study of structure of metals, fusible plugs, aluminum, manufacture of steel, electrically hardened lead, high-speed and carbon twist drills, corrosion of aluminum alloys, tensile strength of steels at various temperatures, merits of aluminum and copper tubing, welding of steel, gases in steel, deoxidation of steel, corrobility of chromium steels, metals for wash boilers, etching reagents, galvanizing lead magnesium alloy, failure of iron pipe, protection of molds from hot metals, stainless steel, automobile headlight specifications, magnalite, diaphragms, compression test for bronzes, method of test for bronze-bearing metals, failure of chilled cast-iron freight wheels, welded rail joints, Mendall metal, tensile properties of structural alloy steels, manufacture of tin plate, brazed copper sheets, substitutes for tin foil, copper roofing sheets, white metal bearing alloy, steels for boiler tubes, bright annealing, aluminum cable, working of 35 per cent nickel steel, effect of zinc plating on the physical properties of streamline wire, corrosion of duralumin, and methods of welding practice.

Publications.

Publications by members of the metallurgical staff appearing during the year are as follows:

Steel rails from sink-head and ordinary ingots (G. K. Burgess), Tech. Paper 178; also Chem. and Met. Eng. (November, 1920), 23, pp. 921–5, 969–75, 1017–22.

Governmental research (G. K. Burgess), Transactions Royal Canadian Inst., Toronto, V. XIII, No. 1; also Scientific Monthly, October, 1920, pp. 341–352.

The microscope and the heat treatment of steel (G. K. Burgess), yearbook Am. Iron and Steel Inst., 10 (1920), pp. 154–173.

Results of tests of centrifugally cast steel (G. K. Burgess), address before Am. Soc. for Steel Treating, Philadelphia Chapter, Feb. 16, 1921; Transactions of Society, 1, p. 370, 1921.

Properties of steel at high temperatures and their relation to heat treatment (G. K. Burgess), address before Am. Soc. for Steel Treating, Washington Chapter, Mar. 18, 1921.

The metallurgical work of the Bureau of Standards, address before American Society for Steel Treating, Cleveland Chapter, Feb. 25, 1921, and before Lehigh Chapter, Bethlehem, Pa., October 18, 1920.

A study of the relation between the Brinell hardness and the grain size of annealed carbon steels (H. S. Rawdon and Emilio Jimeno-Gil, University of Oviedo, Spain), Sci. Paper 397.

The use of ammonium persulphate for revealing the macrostructure of iron and steel (H. S. Rawdon), Sci. Paper 402; also Iron Age, v. 106, p. 965 (October, 1920).

Electric-arc welding of steel: I. Properties of the arc-fused metal (H. S. Rawdon, E. C. Groesbeck, and L. Jordan), Tech. Paper 179.

Physical properties of arc-fused steel (H. S. Rawdon, E. C. Groesbeck, and L. Jordan), Chem. and Met. Eng. 23, p. 677–84.

Metallography of arc-fused steel (H. S. Rawdon, E. C. Groesbeck, and L. Jordan), Chem. and Met. Eng., 23, p. 777–84.

Notes on electric welding (H. S. Rawdon), Mech. Eng., 42 (1920), pp. 567–571; reprinted in Electric Railway Eng., 11 (1920), pp. 441–446.

Metallographic etching reagents (I), for Copper (H. S. Rawdon and Marjorie G. Lorentz), Sci. Paper 399.

Some types of nonferrous corrosion (H. S. Rawdon), Trans. Am. Elec. Soc., 38 (1921, corrosion symposium).

The presence of internal fractures in steel rails and their relation to the behavior of the material under service stresses (H. S. Rawdon), symposium held by Faraday Soc. (London), April, 1921; Jour. of Faraday Soc., 1921; reprinted in Eng. (London), 111, p. 470.

Some observations on season cracking (H. S. Rawdon), contribution to discussion of "Season cracking of brass," Jour. of Inst. of Met., 25, 1921.

The thermal characteristics of arc-fused steel (H. S. Rawdon), contribution to discussion of "Heat treatment of arc welds," Welding Eng., 6 (May, 1921), pp. 44–46.

Macroscopic examination of metals (H. S. Rawdon), Chem. and Met. Eng., 24, pp. 385–7.

Preparation of small specimens for microscopic examination (H. S. Rawdon), Chem. and Met. Eng., 23, pp. 475–6.

Effects of metallic structure upon properties (H. S. Rawdon), Chem. and Met. Eng., 23, pp. 523–7.

The structure and related properties of metals (H. S. Rawdon), address Am. Soc. Steel Treating, Philadelphia Chapter (May 27, 1921), Transactions of the Society, 1; 1921.

The use of X rays in the examination of steel (H. S. Rawdon), Metal Heating, 1, pp. 14–18; reprinted from 1919 Yearbook of Am. Iron and Steel Inst.

Welding practice (H. S. Rawdon), Letter Circular VIII–8.

Experiments in copper crusher cylinders (A. I. Krynitsky), Tech. Paper 185.

The high temperature treatment of high-speed steel and its relation to secondary hardening and to red-hardness (H. Scott), Sci. Paper 295; also Transactions Am. Soc. for Steel Treating, 1, pp. 511–26; 1921.

Thermal and physical changes accompanying the heating of hardened carbon steels (H. Scott and Gretchen H. Movius), Sci. Paper 396.

Motion pictures in the mechanical testing laboratory (H. J. French), Chem. and Met. Eng., 24, p. 131; 1921.

Review of recent Japanese metallurgical investigations (H. J. French), Chem. and Met. Eng., 24; Microstructure of chromium steels, pp. 703–6; Recent work on chromium-tungsten steels, pp. 573–5; Structure of Tungsten Steels, pp. 745–8.

New deoxidizers for steel manufacture (J. R. Cain), Chem. and Met. Eng., 23, pp. 879–802.

Some properties of white metal-bearing alloys at elevated temperatures (R. W. Woodward and J. R. Freeman, jr.), Tech. Paper 188; also Jour. Soc. Auto. Eng. V. VIII, p. 149; February, 1920.

Recent developments in light aluminum alloys (R. W. Woodward), Report of National Advisory Committee for Aeronautics, 1920.

Sources of information and data on metals and alloys (R. W. Woodward), Letter Circular VIII–4, revised edition.

Cast iron for locomotive cylinder parts (C. H. Strand), Tech. Paper 172.

Nickel (P. D. Merica), Circular 100; also Chem. and Met. Eng. 23 (1921), pp. 17–21, 73–6, 197–200, 291–4, 375–8, 558–60, 649–53.

Aircraft steels, discussion of Prof. Sauveur's paper (G. K. Burgess), Trans. Am. Ins. of Min. and Met. Eng., 62, pp. 339–340; 1920.

Prevention of columnar crystallization by rotation during solidification (Howe and Groesbeck), Trans. Am. Ins. of Min. and Met. Eng. 62, pp. 341–346; 1920.

Mechanical properties of steel at elevated temperatures, below the critical range (H. J. French), contribution to discussion of "Comparative tests of steels at high temperatures", Proc. Am. Soc. for Test. Mate.; 1921.

The following are publications in press:

The manufacture and properties of steel plates containing zirconium and other elements (G. K. Burgess and R. W. Woodward).

Thermal stresses in chilled iron car wheels (G. K. Burgess and R. W. Woodward).

Tests of centrifugally cast steel (G. K. Burgess).

The structure and related properties of metals (H. S. Rawdon), Circular 113.

Metallographic testing, revised edition (H. S. Rawdon), Circular 42.

The effect of phosphorus upon the structure of low-carbon open-hearth steels (E. C. Groesbeck).

The structure of metals and alloys (H. S. Rawdon), American Machinist.
The effect of heat treatment upon the properties of one per cent carbon steel (H. J. French and W. G. Johnson).
The elements of heat treatment of steel (H. J. French), American Machinist.
An instrument for measuring the elongation of broken tensile specimens (R. W. Woodward), Chem. and Met. Eng.
Properties of metals and alloys (R. W. Woodward), American Machinist.
Some mechanical properties of monel metal (P. D. Merica and R. G. Waltenberg), Proc. Am. Soc. for Test. Mat., 1921.
The erosion of machine-gun barrels (W. W. Sveshnikoff), Tech. Paper 191.
Note on the properties of antimonial lead (J. S. Hromatko and L. J. Gurevich), Chem. and Met. Eng.
Effect of temperature, deformation, and rate of loading upon the tensile properties of low-carbon steels (H. J. French).
Experiments on the artificial seasoning of gage steels (H. J. French), Chem. and Met. Eng.
The intercrystalline embrittlement of soft metals as a result of corrosion (H. S. Rawdon, A. I. Krynitsky, and J. F. T. Berliner).

9. CERAMICS.

This division is concerned with the study of the principles involved in the production of the many kinds of clay products, such as the various structural materials, pottery, electrical porcelain, and refractories, the manufacture of the different types of glass, including that used for optical purposes, and the enameling of metals. Owing to the fact that these industries are of basic importance in the development of the country and have received but limited systematic technical study, the prosecution of researches tending to assist in the more rapid expansion of these industrial activities is of considerable importance.

CLAY PRODUCTS.

High-Fire Porcelain Glazes.

This investigation was undertaken for the purpose of supplying needed information on high-fire porcelain glazes of the Seger cone type, maturing between cones 12 and 16, the available information as to compositions suitable for commercial application in the manufacture of such materials as chemical porcelain, spark plugs, and pyrometer tubes, and on the softening points of various glazes of this class being extremely meager. Important information has been gained, including the limits of composition for glazes of this type. A report of the results is in process of publication as a technological paper.

Earthenware Bodies and Glazes.

Although much attention has been given to the prevention of the crazing of pottery, this trouble still appears at intervals, and the loss is sometimes exceedingly heavy. In view of this condition, a further study of problems related to crazing has been made, with special attention to the composition of typical pottery bodies and glazes. Results indicate that probable variations occurring from time to time in the silica content of the clays in the bodies would not be sufficient to account for the occasional recurrences of crazing. It was found that a modification of the glaze composition by decreasing the sodium oxide or feldspar and increasing calcium oxide or by substituting silica for feldspar has the effect of reducing the crazing tendency. The lowest softening points were obtained when the refractory portions of the glaze were included in the frit, but this procedure had no apparent effect on the crazing.

Solubility of Some Feldspar Frits.

A large range of feldspar frits for earthenware glazes has been studied to determine the limits of composition within which frits of sufficiently low solubility to prevent loss during the grinding and at the same time of proper fusibility could be obtained. The results of the investigation have been prepared for publication.

Properties of Foreign and Domestic Ball Clays.

The question of suitable ball clays has become one of genuine concern to American potters and other manufacturers of ceramic products in which ball clays are used. English ball clays are still depended on to a considerable extent, although the supply is becoming more uncertain, the cost is excessive, and the quality somewhat variable. A considerable number of good American ball clays are available, but at present the information as to how their properties compare with those of the English ball clays is not sufficient to enable manufacturers to make substitutions with satisfactory assurance as to results. In order to assist in improving this situation, the Bureau is making a study of the properties of a large number of commercial ball clays, both foreign and domestic. The work includes the determination of water, of plasticity, drying and burning behavior, maturing temperature, viscosity of slip, bonding power, and color effect in porcelain bodies. This work is nearing completion.

Hopi Indian Pottery.

The pottery made by the Hopi Indians is fired in an extremely crude way, resulting in high loss due to its fragility. The proper temperature for firing this material in order to produce sufficient strength without destroying the delicate natural coloring of the ware has been determined. A more reliable and vivid stain has been developed for the decoration of this ware. Similar work has also been done for the Zuni Indian School.

Hardness of Glazes.

The question of the hardness of glazes is of particular interest to the manufacturers of white ware, as the hardest glazes would naturally be those most resistant to knife marks. The hardness of a number of typical glazes for porcelain and chemical ware was studied. The effects of variations in heat treatment as well as in the composition of the glazes were determined. Increase of firing temperature increased hardness. Porcelain glazes were found to be the hardest and white-ware glazes and enamels the softest.

Development of a Satisfactory Chrome-Tin Matt Glaze Maturing Between Cones 04 and 01.

The use of combinations of the oxides of chromium and tin for the production of red glazes is common practice, but the results tend to be erratic. In the case of wall tile uniformity of color is especially important. In the work done a number of promising combinations have been developed. Washing the saggers with the glaze has been found to be essential to satisfactory results.

The Effect of Replacements of Sand Flint by Cryptocrystalline Flint in Pottery Bodies.

Certain troubles in pottery manufacture are attributed to the sand flint used in the pottery bodies, and it is of importance that the effect of the replacement of this material, either wholly or in part, by other available materials should be determined. The possibilities of the so-called cryptocrystalline flint which is available in large quantities in southern Illinois are being investigated. A large amount of work has been done, but the data are not sufficiently complete to justify conclusions.

Safe Rate of Water Smoking.

Clays and shales of various types were studied to determine their behavior in water smoking after different drying treatments. The temperature range of water smoking was found to lie between 100° C. and approximately 225° C. Results indicate that 12° C. per hour should be a safe rate of progress during the water-smoking period for such products as building and paving brick, assuming good ventilation or draft in the kilns.

Casting of Terra Cotta.

A study of the possibilities of the casting process for improving the quality or reducing the factory cost of architectural terra cotta has supplied information to the effect that very few of the terra-cotta bodies now in use possess good casting properties. They could, of course, be modified by a suitable substitution of clays, but this would probably involve increased cost of materials in some cases. The mechanical difficulties to be encountered appear somewhat formidable and make the extensive application of the casting process in this industry of doubtful practicability at the present time.

Effect of Time of Drying on Total Shrinkage of Clays.

A number of typical shale ball clays and fire clays were studied. Under laboratory conditions, increasing the drying temperature at different rates to a maximum of 100° C., it was found that the required drying time depends largely on the water content and the structure of the clay, but that the total shrinkage is independent of the drying time.

The Use of Special Oxides in Porcelain Bodies.

The investigation includes a study of the results obtained with the oxides of zirconium, thorium, and titanium and the rare-earth oxides of cerium, lanthanum, and didymium and the silicate of zirconium. Drying and burning behavior, color, structure, mechanical strength, and dielectric resistance were determined for bodies in which these oxides were substituted for flint. Zirconium oxide produced the best porcelain from all standpoints, while the zirconium silicate body tended to overfire easily when used in combination with feldspar. The rare-earth oxides proved undesirable in every way. Thorium and titanium did not prove satisfactory. None of the oxides affected the dielectric resistance. Some very satisfactory bodies for pyrom-

eter tubes, cooking ware, and electrical heating devices were developed. The results of this investigation are being compiled for publication as a technologic paper.

Cooperative Investigation of Problems Relating to Architectural Terra Cotta.

A large amount of work in this investigation has been made possible by the cooperation of the National Terra Cotta Society. In addition to a continuation of the laboratory work at the Bureau, an extensive program of field observations on the condition of terra cotta in buildings under different conditions in various parts of the United States and Canada has been carried out. In the laboratory a large amount of work has been done in correlating the porosity and absorption of different bodies burned to a number of different temperatures with the tensile strength, in addition to the transverse resistance and the resistance to sodium sulphate treatment and to actual freezing. Expansivity measurements have been made on a considerable number of bodies and glazes in connection with the question of glaze fit and the rôle played by glaze composition in the failure of terra cotta. Work has been started in the study of the effect of the rate of cooling on the subsequent resistance of terra cotta to temperature changes and other agencies.

OPTICAL GLASS.

Scope of Work.

The work of this section covers the (1) making of optical glass; (2) the molding of optical shapes, such as lens blanks, prisms, etc., from such glass; (3) the annealing of glass; and (4) the improvement and development of specifications for raw materials and for finished optical glass, as well as commercial glass for various industrial uses.

Melting.

During the past year this section has made 33 experimental melts of various kinds of glass, representing about 30,000 pounds, including borosilicate crowns, light and dense barium crowns, ordinary and barium flints.

Molding.

Considerable progress has been made in the development of a satisfactory technique in the molding of moderately large lens and prism blanks by the "sticking-up" process. Blanks for 3-inch right-angled prisms, which would be difficult to mold by the usual paddling process, have been successfully molded by this process, and troubles with cracking, folds, etc., have been largely eliminated. Experimental work on the making of large slabs and disks by melting down rough pieces of optical glass in clay molds has been continued. Disks for lenses of approximately 15 inch diameter have been made and equipment for molding larger disks has been installed.

Annealing.

Scientific work of the Bureau of Standards on the annealing of glass has previously been reported. The findings of this investigation have been applied during the year to the annealing of optical glass of different kinds in various sizes and shapes. The results

indicate that the problems involved are more complex than has previously been realized.

Due to the necessity of precise control of temperature conditions in furnaces for the fine annealing of pieces of even moderate thickness it has been found necessary to design an electric annealing furnace of considerable size with provision for automatic temperature control. This furnace is in process of installation.

Optical Glass for Navy Department.

One of the fundamental purposes of the optical glass section is to assure the availability of optical glass for scientific and military purposes from domestic sources. In the course of experimental work on types of glass suitable for military optical instruments considerable quantities of glass of the highest quality are produced, and a large proportion of such glass is supplied, by special arrangement, to the Navy Department in the form of molded blanks and slabs. During the past year these deliveries have amounted to slightly more than 1,500 pounds, distributed as follows: Two hundred and eighty-six medium flint lens blanks, 114 pounds; 1,758 light barium crown lens blanks, 323 pounds; 1,357 borosilicate crown prisms, 450 pounds; slabs and miscellaneous shapes, 672 pounds.

In addition to this the special requirements of the Bureau of Standards for optical glass for use in research work have been supplied.

Investigation of Colored Glass.

In addition to investigations incident to the manufacture of optical glass for lenses, prisms, etc., the development of colored glasses suitable for screens for use in naval telescopes and similar instruments is also receiving considerable attention. Promising results have recently been obtained from the work on neutral glasses for this purpose.

Specifications.

The preparation of specifications for the purchase of glass articles, such as tableware and sheet glass, by the various Government departments has been undertaken by this section. This work has progressed to the extent of obtaining the opinion of numerous manufacturers and dealers as to what such specifications should comprise and obtaining samples for test.

Cooperation.

This section is cooperating with the interdepartmental conference on chemical lime in the preparation of specifications for lime to be used in glass manufacture. The specifications have been drafted and submitted to representatives of interested technical societies and manufacturers for approval.

Information.

Numerous requests for information relative to the various phases of commercial and optical glass manufacture are being received. The information requested includes opinions as to the quality of raw materials used in glass making, formulæ for various kinds of glass,

methods of manufacture, coloring agents, annealing, causes of various defects, testing, etc. In order to facilitate answering some of these inquiries and to furnish more detailed information, material for a publication regarding the manufacture of commercial glass has been collected.

REFRACTORIES.

Transverse Strength of Fire-Clay Tile.

Reliable data on the transverse strength of fire-clay tile have been greatly needed by furnace designers. Such data have now been made available by transverse strength tests of tile at various temperatures. Tests were made on tile obtained from a number of manufacturing districts in different parts of the country, and these were supplemented by tests of tile made in the laboratory. A fairly good conception of what can be obtained in the way of strength from fire-clay tiles of moderate thickness supporting loads over bridged gaps may be gained from the following figures, which give the average modulus of rupture of all the commercial tile tested for each of four temperatures. None of the brands tested gave results sufficiently high to exclude them from the conclusions to be drawn from these data, and none of the tile made in the laboratory gave promise of the attainment of great improvement on these values by the use of special mixtures of fire clays and fire clay grogs. Temperature (centigrade), 1,275, 1,300, 1,325, 1,350; modulus of rupture (pounds per square inch), 245.5, 98.7, 54.2, 29.5.

These results obviously indicate an extremely rapid falling off of strength above 1,275° C., and when the effect of time is taken into account it becomes evident that the transverse strength above 1,300° C. is a negligible quantity from the standpoint of design.

Study of Bond Clays for Glass Pots.

A comparison was made between the significant properties of the Gross-Almerode clay and a series of mixtures of American bond clays to determine how closely such mixtures approximate the nature of the Gross-Almerode clay and whether any of these mixtures when used in a glass-pot body resist the action of a corrosive glass as well as a body made from the Gross-Almerode clay. None of the mixtures tried equaled the Gross-Almerode clay in point of low-water requirement for plasticity and low shrinkage, but some of the bodies made from American clays resisted corrosion better than the body bonded with the Gross-Almerode clay.

Combinations of Siliceous Clay with Aluminous Grog Compared with Reverse Combinations.

This work was done for the purpose of determining the superiority of one of the two types of glass-pot bodies; i. e., the type in which an aluminous grog is bonded with a siliceous clay or clay mixture and the type in which the grog is siliceous and the bond clay aluminous. The results indicate the superiority of the former type.

Special Material for Refractory Tubes.

In order to furnish refractory tubes suitable for some special work under the direction of Dr. Mendenhall, a considerable amount of experimental work was done, which resulted in the development of a

body suitable for the making of tubes which has a softening point of approximately 1,760° C. and resists rapid heating and cooling.

ENAMELS.

Elimination of "Fish Scaling" of Enamels on Iron and Steel.

The tendency to "fish scaling" is one of the most costly and the least understood of the troubles of the enameler. The Bureau has made an exhaustive study of this problem and has succeeded in determining the causes of the tendency and in finding practical means for correcting it. It has been demonstrated by expansivity measurements that "fish scaling" is due, primarily, to differences between the coefficients of expansion of metals and of the enamels with which they are coated, the enamel being in compression at ordinary temperatures. A second cause is the poor adhesion of the enamels to the steel. Suitable compositions of enamel minimize the difference in contraction of the enamels and steel and are a factor in increasing the strength of the enamels. It has also been determined that suitable mechanical treatment of the metal previous to enameling reduces, and in certain cases eliminates, any tendency to "fish scaling" by providing a better bond. This is in accord with observation of the behavior of enamels on what is termed "drawn or spun ware."

Having succeeded in developing practical methods for correcting the "fish-scaling" tendency, the Bureau has started a program of cooperation with both metal manufacturers and enamelers for the purpose of applying these methods on a commercial scale. Metal stock now being prepared in the mills will be fabricated and enameled in five enameling plants. It is the purpose of the Bureau to publish a combined report of this laboratory investigation and the factory application in the form of a technologic paper.

Wet-Process Enamels for Cast Iron.

The dry process of cast-iron enameling is well suited to the coating of such large objects as bathtubs and sinks, but is not adapted to the manufacture of such articles as stove fittings, where the ware is small and volume production is desired. Actuated by requests from a number of stove manufacturers, the Bureau has undertaken an investigation of methods for the production of wet enamels. An extended study has been made of both ground coats and cover coats and a number of satisfactory compositions have been developed. This work is nearing completion.

White Enamels for Copper.

The Bureau has in the past had a number of requests for compositions of enamels and information regarding technique for the enameling of copper. While it has not been possible to make an extended investigation of this subject, some 20 compositions have been studied. Several of these are promising. Essential knowledge as to technique has been gained. The results of this work will appear in a paper in a forthcoming number of the Journal of the American Ceramic Society.

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Relation of Composition of Enamels to Solubility in Acids.

The work on this investigation was completed in the past year and the results will be published in a forthcoming number of the Journal of the American Ceramic Society. Some excellent acid resistant enamels for application to cast iron by the dry process have been developed and important information relative to the effect of composition on the acid resistance and adherence of this type of enamel has been obtained.

Replacement of Tin Oxide in Enamels for Sheet Steel.

Substitutes for tin oxide in enamels are offered from time to time, and to determine the comparative effect of these substances on opacity a number of them have been applied in enamels for steel. Another phase of the problem is the development of a method for establishing definite comparative values for the opacity of the various enamels. The colorimetry section of the Bureau is cooperating in making these determinations by means of the spectrophotometer. The preliminary results so far obtained are most promising, and it appears that the instrument could be used to obtain a quantitative figure showing the value of any substitute as an opacifier alone.

TESTING AND INFORMATION.

One of the functions of the division is the testing of ceramic materials for the various Government departments and in certain cases for outside parties. During the past year 134 tests on fire brick have been made for the Panama Canal Commission. These included fusion tests, endurance of high temperatures under load, and tests for spalling. Twenty-five tests on refractory materials were made for outside parties.

Thirty-four reports of preliminary tests on clays submitted were prepared. These preliminary tests are made for the purpose of determining whether a material is of such a nature as to justify a more thorough investigation of its properties.

Twelve feldspars from various sources were tested during the year with a view to supplying information as to whether the deposits from which they were obtained were of sufficient promise for further exploitation. A number of those examined proved to be of excellent quality. This work is of importance because of the fact that sources of supply of this essential material are somewhat limited.

In addition to the reports of actual tests the division has been able to be of service to a number of the Government departments by supplying information and assisting in the preparation of specifications for ceramic materials. The departments assisted include the Panama Canal Commission, the United States Geological Survey, the Navy and War Departments, the Department of the Interior, the Department of Agriculture, the Public Health Service, and a number of State geological surveys.

A large amount of information bearing on specific problems of manufacturers has been furnished, and in many cases it has been possible to render assistance in the correction of serious difficulties.

Cooperation with Technical Societies.

Through members of its staff the division has participated actively in the work of the American Ceramic Society, the American Society for Testing Materials, the National Terra Cotta Society, and the National Fire Protection Association. A large part of this work is along the line of the development of standard tests and the establishment of standards for materials and for the construction of buildings.

Cooperation with Commercial Organizations.

In addition to the work that is being done in cooperation with the National Terra Cotta Society the division has taken part in the research on the properties of hollow building tile which the Bureau is carrying out in cooperation with the Hollow Building Tile Association. Work has been started on the Bureau's part in an investigation in cooperation with an association of heavy clay products' manufacturers, and arrangements have been made for a cooperative study of special problems of the Associated Tile Manufacturers.

PUBLICATIONS.

During the year the following reports have been published. A number of these are in the nature of progress reports and have been published in outside publications in order to make the information available as early as possible. Reports of completed investigations are published in the form of technologic papers of the Bureau.

Technologic Paper 165, Enameling of sheet iron and steel.
Classification of enamels for sheet steel, Jour. Am. Cer. Soc., 3, No. 12.
Note on porcelain glass-pot mixtures, Jour. Am. Cer. Soc., 3, No. 7.
The rate of vitrification of porcelain molded under different conditions, Jour. Am. Cer. Soc., 3, No. 10.
Possibilities for research and development in the field of refractories, Chem. and Met. Eng., Dec. 15, 1920.
Note on the effect of time on the drying shrinkage of clays, Jour. Am. Cer. Soc., 4, No. 4.
The watersmoking of clay, Jour. Am. Cer. Soc., 4, No. 5.
Refractories for electric furnaces, report of meeting of Oct. 6, 1920, of the Electric Furnace Association.
The solubility and fusibility of some feldspar frits, Jour. Am. Cer. Soc., 4, No. 6.
The absorption of sodium hydroxide by kaolins, Jour. Am. Cer. Soc., 4, No. 6.

III. THE OFFICE.

Office management, publications, information, personnel, fund accounts, purchases, property and stores, mail and files, scientific library, transportation and communication, tests, and general clerical and secretarial work.

GENERAL.

The activities of the office, briefly stated in round numbers for the past year, were as follows: General clerical work, secretarial and office management of the clerical work of the divisions, correspondence, certificates and reports of tests and investigations, and records pertaining thereto; editorial and proof inspection for manuscripts submitted for publication, resulting in 110 new publications, approximately 6,000 new pages of printed matter, about 180,000 separate pamphlets; appropriated and transfer fund accounts for Bureau expenditures, amounting to nearly $1,750,000; personnel work comprising all changes of staff status and records therefor, involving about 2,500 personnel changes and a net turnover of 50 per cent of Bureau staff; special and regular purchases (for which 15,000 scientific and industrial catalogues are available), involving over 5,000 orders; accountability records for 155,000 items of inventoried apparatus, machines, tools, and other equipment, including the accession of 13,000 additional pieces; record and distribution of mail (more than 175,000 official communications, an increase of 25,000 pieces); supervision of the scientific library of 21,000 volumes in the fields of physics, chemistry, engineering, and mathematics; collation and furnishing of technical information, issuance of a technical news bulletin giving industrial experts the results of Bureau investigations, including supervision of the official distribution of Bureau publications.

FINANCE.

Funds.

The regular appropriations of the Bureau amounted to $1,304,632. Additional items approximating $35,000 were carried in the first deficiency act and $15,000 of the public utility standards appropriation for 1922 was made immediately available, making a net total of $1,354,632. There were transferred to the Bureau from other departments for cooperative investigational work, under authority contained in the legislative, executive, and judicial act of May 29, 1920, the sum of $369,992, and reimbursements were also received in the amount of $16,014.17, making the total available for obligation $1,740,638.17.

Appropriation Statements.

The following statement shows the amount and object of each appropriation provided for the Bureau for the fiscal year 1921, the disbursement during the year, the amount of unpaid orders at the

close of the year, and the unexpended balance remaining at the close of business June 30, 1921:

Appropriation.	Total appropriation.	Disbursements.	Liability.	Balance.
Salaries	$432,360.00	$403,915.67	$17,151.60	$11,292.73
Equipment	[1] 95,330.00	59,932.58	32,099.23	3,268.19
General expense	75,000.00	46,417.34	25,094.11	3,488.55
Grounds	10,000.00	8,206.85	1,745.54	47.61
Testing structural materials	125,000.00	118,165.91	6,347.96	486.13
Testing structural materials (interior civil)	2,250.00		1,882.64	367.36
Testing machines	30,000.00	28,686.05	1,267.74	46.21
Metallurgical research	[2] 25,061.01	23,572.51	1,411.59	76.91
Optical glass	[3] 31,000.00	24,839.34	58.49	6,102.17
Additional land	47,272.00	47,272.00		
Investigation of textiles	[4] 15,680.00	14,070.40	1,533.27	76.33
Sugar standardization	[5] 31,800.00	28,697.77	3,066.35	35.88
Gauge standardization	[6] 46,183.00	40,889.34	3,878.07	1,415.59
High-temperature investigation	10,000.00	7,055.87	2,909.75	34.38
Testing railroad scales	40,000.00	36,091.19	3,625.13	283.68
Investigation of fire-resisting properties	25,000.00	21,184.99	3,642.25	172.76
Investigation of railway materials	15,000.00	13,347.87	1,442.03	210.10
Testing miscellaneous materials	30,000.00	27,159.60	2,840.30	.10
Investigation of public utility standards	[7] 85,272.86	84,725.81	333.83	213.22
Radio research	[8] 30,096.00	27,243.57	2,681.75	170.68
Industrial research	[9] 419,717.46	315,219.21	88,578.99	15,919.26
Sound investigation	[10] 7,000.00	6,057.66	904.53	37.81
Clay products	25,000.00	22,380.43	2,391.08	228.49
Color standardization	10,000.00	9,069.35	692.34	238.31
Standardizing mechanical appliances	[11] 35,000.00	29,299.43	5,461.29	239.28
Investigation of mine scales and ears	15,000.00	9,072.30	3,692.50	2,235.20
Standardization of equipment	15,000.00	5,988.97	3,623.48	5,387.55
Total	1,729,022.33	1,458,592.01	218,355.84	52,074.48

[1] Includes reimbursement of $330 received from other departments.
[2] Includes reimbursement of $61.01 received from other departments.
[3] Includes reimbursement of $6,000 received from other departments.
[4] Includes reimbursement of $680 received from other departments.
[5] Includes reimbursement of $1,800 received from other departments.
[6] Includes reimbursement of $6,183 received from other departments.
[7] Includes reimbursement of $272.86 received from other departments.
[8] Includes reimbursement of $96 received from other departments.
[9] Includes reimbursement of $369,717.46 received from other departments.
[10] Includes reimbursement of $2,000 received from other departments.
[11] Includes reimbursement of $20,000 received from other departments.

The following statement shows the condition of the appropriations for the two preceding fiscal years at the close of business June 30, 1921:

Appropriation.	Total appropriation.	Disbursements.	Liability.	Balance.
FISCAL YEAR 1919.				
Salaries	$432,360.00	$375,860.09	$7.96	$56,491.95
Equipment	[12] 81,200.00	74,745.24	1,619.80	4,834.96
General expenses	[13] 50,100.76	46,279.93	3,093.55	727.28
Grounds	7,500.00	7,285.82		214.18
High potential investigation	15,000.00	14,832.33	14.24	153.43
Testing structural materials	[14] 235,094.14	224,068.76	21.19	11,004.19
Testing machines	30,000.00	29,220.99	214.15	564.86
Investigation of fire-resisting properties	25,000.00	24,705.99	78.07	215.94
Investigation of public utility standards	[15] 55,000.00	54,505.08	357.21	137.71
Investigation of railway materials	15,000.00	14,834.04	29.10	136.86
Testing miscellaneous materials	30,000.00	29,690.20		309.80
Radio research	20,000.00	19,838.41		161.59
Color standardization	10,000.00	9,943.50		56.50
Investigation of clay products	20,000.00	19,766.44	31.43	202.13
Determining physical constants	5,000.00	4,972.18	1.60	26.22
Standardizing mechanical appliances	10,000.00	9,911.79		88.21
Investigation of optical glass	[16] 84,388.75	82,134.89	986.38	1,267.48
Standard materials	4,000.00	3,833.24		166.76

[12] Includes reimbursement of $200 received from other departments.
[13] Includes reimbursement of $100.76 received from other departments.
[14] Includes reimbursement of $110,094.14 received from other departments.
[15] Includes reimbursement of $5,000 received from other departments.
[16] Includes reimbursement of $64,388.75 received from other departments.

Appropriation.	Total appropriation.	Disbursements.	Liability.	Balance.
FISCAL YEAR 1919—continued.				
Investigation of textiles	$10,000.00	$9,864.91		$135.09
Sugar standardization	[17] 21,350.00	20,773.13	$3.75	573.12
Gange standardization	[18] 433,000.00	426,935.68	1,319.75	4,744.57
Renewal of storage batteries	20,000.00	18,695.77		1,304.23
Military research, 1918–19	[19] 622,690.48	617,695.74	1,996.42	2,998.32
Investigation of mine scales and cars, 1918–19	15,000.00	14,714.67	104.20	181.13
Investigation of public-utility companies, 1918–19	[20] 53,522.52	52,713.88	737.49	71.15
Testing railroad scales	[21] 41,104.70	39,166.60	220.60	1,717.50
National security and defense.				
Military researches	100,000.00	97,362.15	549.78	2,088.07
Roberts coke oven	40,000.00	39,748.42	183.01	68.57
Thermit investigation	4,300.00	3,946.75	190.56	162.69
Altitude laboratory	60,000.00	59,897.19		102.81
Power-plant equipment (industrial laboratory)	31,500.00	31,461.01		38.99
Completing laboratories	235,000.00	231,870.41		3,129.59
Armament of fortification (commerce transfer)	[22] 224,333.03	145,506.18	4,317.55	74,509.30
Aviation, Navy, commerce transfer	5,000.00	4,998.28		1.72
Total	3,046,444.38	2,861,779.69	16,077.79	168,586.90
FISCAL YEAR 1920.				
Salaries	486,760.00	461,871.34	618.70	24,269.96
Equipment	[23] 108,033.00	103,388.39	3,972.66	671.95
General expenses	95,000.00	79,145.39	7,129.40	8,725.21
Grounds	7,500.00	7,397.95		102.05
Testing structural materials	[24] 150,718.25	148,175.76	995.59	1,546.90
Testing machines	[25] 35,263.49	34,459.31	174.77	629.41
Metallurgical research	[26] 30,129.97	29,102.44	737.50	290.03
Investigation of optical glass	[27] 63,761.12	62,961.72	450.00	349.40
Standard materials	5,000.00	4,818.75		181.25
Investigation of textiles	15,000.00	14,840.44		159.56
Sugar standardization	[28] 21,800.00	21,056.34		743.66
Gauge standardization	[29] 56,276.90	55,455.94	517.11	303.85
High-temperature investigation	10,000.00	9,930.92		69.08
Testing railroad scales	[30] 43,841.06	42,839.09	52.31	949.66
Investigation of fire-resisting properties	25,000.00	24,255.04	206.06	538.90
Investigation of railway materials	15,000.00	14,649.36		350.64
Testing miscellaneous materials	30,000.00	29,844.68	13.50	141.82
Investigation of public-utility standards	[31] 114,159.82	112,043.91	1,525.43	590.48
Radio research	[32] 31,555.94	30,758.55	625.91	171.48
Industrial research, 1919–20	[33] 71,899.23	69,994.12	25.30	1,879.81
Industrial research, 1920	[34] 291,775.05	286,685.39	2,884.56	2,205.10
Sound investigation	[35] 7,237.04	6,876.72	252.52	107.80
Investigation of clay products	20,000.00	19,824.00		176.00
Color standardization	10,000.00	9,937.25		62.75
Determining physical constants	5,000.00	4,996.00		4.00
Standardizing mechanical appliances	[36] 50,820.26	49,597.72	694.03	528.51
Investigation of mine scales and cars	[37] 15,179.73	15,061.26	12.29	106.18
Industrial safety standards	25,000.00	24,459.32	23.00	517.68
Testing Government materials	[38] 100,182.00	97,454.65	1,703.56	1,023.79
Standardization of equipment	[39] 52,292.00	34,463.83	151.09	17,677.08
Platinum and rare metals	15,000.00	14,982.23		17.77
Retaining wall	20,000.00	17,674.27		2,325.73
Equipping laboratory, 1919–20	100,000.00	98,010.26	950.28	1,039.46
Total	2,129,184.86	2,037,012.34	23,715.57	68,456.95

[17] Includes reimbursement of $1,350 received from other departments.
[18] Includes allotment of $283,000 received from War Department.
[19] Includes reimbursement of $272,690.48 received from other departments.
[20] Includes reimbursement of $3,522.52 received from other departments.
[21] Includes reimbursement of $1,104.70 received from other departments.
[22] Includes reimbursement of $124,333.03 received from other departments.
[23] Includes reimbursement of $33 received from other departments.
[24] Includes reimbursement of $25,718.25 received from other departments.
[25] Includes reimbursement of $5,263.49 received from other departments.
[26] Includes reimbursement of $5,129.97 received from other departments.
[27] Includes reimbursement of $43,761.12 received from other departments.
[28] Includes reimbursement of $1,800 received from other departments.
[29] Includes reimbursement of $16,276.90 received from other departments.
[30] Includes reimbursement of $3,841.06 received from other departments.
[31] Includes reimbursement of $29,159.82 received from other departments.
[32] Includes reimbursement of $1,555.94 received from other departments.
[33] Includes reimbursement of $21,899.23 received from other departments.
[34] Includes reimbursement of $41,775.05 received from other departments.
[35] Includes reimbursement of $2,237.04 received from other departments.
[36] Includes reimbursement of $35,820.26 received from other departments.
[37] Includes reimbursement of $179.73 received from other departments.
[38] Includes reimbursement of $182 received from other departments.
[39] Includes reimbursement of $2,292 received from other departments.

Summary of Tests.

The Bureau's work includes, among other things, a large amount of testing standards, measuring instruments, and materials. Incident thereto, much of the testing involves primarily investigation of the scientific principles underlying the tests, the studying of existing methods, and the development of new standard tests of determinate accuracy. For each test a reasonable fee is charged, except when made for the National or State Governments. The number of tests completed during the year, together with their value, is shown in the following table:

NUMBER AND VALUE OF TESTS COMPLETED,[1] FISCAL YEAR ENDING JUNE 30, 1921.

Nature of test.	For Government.		For public.		Total.	
	Number.	Value.	Number.	Value.	Number.	Value.
Length:						
Tapes	125	$576.90	65	$124.95	190	$701.85
Other length tests	1,439	807.75	2,497	2,267.20	3,936	3,074.95
Mass:						
Weights	1,104	683.10	4,122	1,988.95	5,226	2,672.05
Scales and balances	530	21,027.50	2	26.50	532	21,054.00
Capacity	2,753	1,188.45	7,045	3,407.35	9,798	4,595.80
Hydrometry	164	189.25	475	781.75	639	971.00
Time	5,472	15,738.25	54	129.00	5,526	15,867.25
Electrical tests	832	2,431.85	628	2,357.50	1,460	4,789.35
Photometry [2]	1,805	6,563.00	75	236.50	1,880	6,799.50
Radioactivity	69	73.30	2,111	16,499.82	2,180	16,573.12
Temperature:						
Clinical thermometers	22,338	1,838.53	1,264	143.48	23,602	1,982.01
Other thermometers and miscellaneous	1,610	1,597.97	2,427	5,094.93	4,037	6,692.90
Optical tests:						
Sugar polarimetry	1,574	1,587.80	39	160.00	1,613	1,747.80
Other optical tests	919	857.00	1,519	2,654.70	2,438	3,511.70
Chemical analyses:						
Structural materials	1,070	10,700.00	.....	.....	1,070	10,700.00
Other materials	6,383	101,826.00	.....	.....	6,383	101,826.00
Standard samples	448	837.65	3,430	6,729.35	3,878	7,567.00
Mechanical instruments and appliances	407	1,722.00	78	283.00	485	2,005.00
Acronautical instrument tests	123	1,489.00	9	51.50	132	1,540.50
Physical tests of materials:						
Cement	5,274	40,804.50	7	87.50	5,281	40,892.00
Other structural materials	2,015	5,876.55	105	406.00	2,120	6,282.55
Miscellaneous materials, including paper, textiles, rubber, leather, etc	10,129	44,141.25	538	1,227.60	10,667	45,368.85
Metallurgical tests	611	2,260.00	23	198.25	634	2,458.25
Miscellaneous	204	2,688.25	125	403.80	329	3,092.05
Total	67,398	267,505.85	26,638	45,259.63	94,036	312,765.48

[1] The tests reported in this table include only the tests for which all technical procedure was entirely completed during the year 1920-21.

[2] In addition the Bureau inspected 2,849,564 incandescent lamps at various factories for other departments of the Government, the fees for which would amount to $7,383.60.

PERSONNEL.

During the year the Bureau staff averaged 850 regularly appointed employees—342 statutory employees and about 508 engaged in research and investigations specially authorized by Congress. The statutory positions include 201 scientific positions, 56 office assistants, 50 engaged in the operation of the plant, and 35 in the construction. The total turnover in the personnel for the year was approximately 50 per cent, of which approximately 30 per cent were actual resignations. The personnel on June 30, 1921, consisted of 870 employees, a net reduction of 27 employees during the year.

Death of Two Division Chiefs.

The Bureau has suffered a severe loss in the death of two chiefs of divisions, Dr. Edward B. Rosa, chief of the Electrical Division, and Maj. Louis A. Fischer, chief of the Division of Weights and Measures.

Dr. Rosa died on May 17, 1921, and Maj. Fischer's death occurred as this report was being prepared. These two officers were seniors in point of service, entering the Bureau at the time it was created in 1901. Dr. Rosa was a recognized leader in fundamental electrical researches and was also prominently identified with the preparation of national codes of practice and safety in industrial work. He organized the work of electrical testing, photometry, radio communication, and radio activity, as well as the public-utilities investigations of the Bureau.

Maj. Fischer stimulated a nation-wide interest in the subject of trade weights and measures, and his able cooperation with State and local superintendents and weights and measures inspectors brought about the most cordial relations between the specialists in this field and the Bureau. He also successfully organized the technical sections of the Bureau in charge of measurements of length, mass, capacity, time, pressure, and related subjects.

PURCHASE.

The 5,000 Bureau orders placed during the year comprised 286 exigency orders, 90 special orders through the Division of Supplies, and 4,300 regular orders. The purchase office handled 2,222 proposals covering the needs of practically every laboratory of the Bureau following the essential Government routine. A systematic record of bids and purchases is maintained to aid the Bureau's staff and facilitate the purchase work. The section also prepared all formal contracts for larger purchases and enterprises and handled 725 travel authorizations and the records incident thereto.

PROPERTY AND STORES.

This section administers the accession, distribution, and accountability of property, the records of property, both equipment and supplies, and also the work of receiving and shipping instruments and materials of all kinds, including the packing and shipping of all instruments tested by the Bureau. These functions include the receiving at the shipping room and delivery trucking. With the new space assigned for the main storeroom, this branch will be adapted to serve the needs of the Bureau more efficiently.

During the year approximately 60,200 items of supplies and property were received and inspected by the staff in charge of property and stores. The inventoried items of equipment included 13,400 pieces of apparatus and other equipment. Supplies were dispensed by the storeroom to the value of approximately $58,000. Approximately 12½ tons of instruments and other technical materials pass through the shipping room per week, and 6 tons of additional transportation is required outside of the shipping room.

MAIL AND FILES.

Volume of Mail.

The volume of mail handled shows an increase of about 25,000 pieces over the previous fiscal year, totaling approximately 175,000 pieces. This number includes only first-class mail addressed to the Bureau and dictated replies thereto, taking no account of the large number of incoming and outgoing form letters and incoming second-class and other mail handled by the mail room, about 100,000 additional pieces per year. Intrabureau communications average about 500 per day. Of the 175,000 pieces of mail 130,000 are brief indexed. An automatic index for the files of index slips was installed during the year and minimized the liability of misfiling.

Model Letters and Clerks' Instructions.

A 53-page "Standard office practice" was issued to the clerks during the year. It contains the general regulations, model forms, standard modes of address, and samples of the correct usages for guidance in the preparation of letters and other communications, certificates of test, manuscripts, and reports. Daily inspection of outgoing mail as to compliance with standard practice is conducted by this section. Supplementary to the "Standard office practice" 11 sheets of "Office notes" were issued to the clerks reminding them of existing practice, approved changes in practice, and new rulings as to procedure. These have brought uniformity in the clerical work of the Bureau with excellent results.

LIBRARY.

The work of the librarian includes the maintenance of the Bureau's collections of scientific and technical books and periodicals with card catalogues of the same, bibliographical work, selection of new reference books, preparing book lists for prospective accessions, accessioning of new books, loans and accountability records, assistance to technical staff in locating sources and data, and the binding of books and periodicals.

Accessioned Volumes.

At the close of the year the technical library of the Bureau contained 21,284 accessioned volumes. Except for a few law books these are all of scientific and technical character, chiefly in the subjects of physics, chemistry, engineering, and special technology. During the fiscal year 1,998 new volumes were accessioned.

Technical Journals.

The Bureau receives currently 563 scientific and technical periodicals. About one-half of the periodicals are received by exchange. The technical journals currently received comprise 229 American, 132 British (and others in English), 61 French, 107 German, 34 others, having in all 9,547 parts a year. Besides these, 275 other nontechnical periodicals, including yearly reports, are received having 1,580 parts, making a total of 11,127 parts handled during the year.

Circulation.

Most of the consultation of books is in the library and at points where desk copies of important texts and reference books are assigned throughout the laboratories. Besides such regular consultation, however, a monthly average circulation of 600 books and journals was maintained throughout the year. By a cooperative arrangement with the various libraries in Washington and outside 491 loans were made to the Bureau. In return the Bureau makes loans to experts in other institutions and tenders the facilities of its library for consultation and reference.

INFORMATION.

The information section has charge of the collation and dissemination of technical information, including the distribution of the scientific and technical papers of the Bureau, which are the most important means of rendering the results of the Bureau's research available to the public.

Technical Documents.

Special and confidential documents received at the Bureau and not deposited at the library have been filed or distributed to the various scientific divisions as heretofore. The number of such documents received, however, has considerably diminished.

Special Reports.

Several reports describing the general work of the Bureau as well as special investigations where such reports are of a more or less popular character have been prepared by the section for other Government organizations, technical journals, and the daily press.

The Technical News Bulletin has been issued each month to give prompt announcement of Bureau researches to industrial experts, research laboratories, and technical libraries, with a view to securing prompt use of the Bureau's data in the industries.

Directing Inquiries.

Incoming inquiries by mail and telephone are routed to members of the staff best qualified to answer the questions. In the case of general inquiries concerning the functions of the Bureau, the answer is prepared or given directly by this section. Many letters are received each week from newspaper information bureaus, and the routing of these communications forms part of the work of the section.

PUBLICATIONS.

Distribution.

Last year's report mentioned the requests for effective means of keeping the public informed of the results of the Bureau's work. During the past year special attention has been given to the announcement of new publications which is now handled effectively in several ways: (*a*) Announcements in the monthly list issued by the Superintendent of Documents, of which a large edition is circulated; (*b*) announcements in the monthly list of Department of Commerce

publications, of which more than 10,000 copies are distributed to journals, industrial concerns, and libraries; (*c*) technical abstracts of all new publications distributed to the technical press; (*d*) announcements in the monthly issues of the Bureau's Technical News Bulletin, and (*e*) publication of title and abstract in the descriptive list of the Bureau's publications, Circular 24 and supplements thereto; (*f*) an advanced copy of each new publication is sent with a personal letter to the editor of selected technical journals directly concerned with the subjects treated; and (*g*) in addition to the above copies of Bureau publications are sent by the Superintendent of Documents by provision of law to selected libraries throughout the country known as "Government depository libraries," which undertake to keep the publications available for consultation by the public.

Publications Issued During the Year.

During the fiscal year just closed the Bureau has issued 86 new publications, a supplement to the Bureau's list of publications, and 24 reprints, 110 publications in all. The 86 new publications comprise 33 scientific papers, giving the results of scientific researches; 27 technologic papers, giving results of new investigations in the field of engineering and general technology; 18 circulars, containing important compiled technical information in the Bureau's field and useful to the industries, and especially to scientific and technical laboratories; 3 handbooks and 5 miscellaneous publications. The new series of handbooks has been added during the fiscal year and comprised the weights and measures manual, two safety codes, and similar regulations prepared by the Bureau.

The following publications were issued during the year:

SCIENTIFIC PAPERS.

Spectrophotoelectric sensitivity of thalofide.
An electron-tube transmitter of completely modulated waves.
Testing of magnetic compasses.
Measurement of hysteresis values from high magnetizing forces.
Variation of residual induction and coercive force with magnetizing force.
A new microphotometer for photographic densities.
Atomic theory and low-voltage arcs in cæsium vapor.
Permeability of rubber to gases.
Adjustment of parabolic and linear curves to observations taken at equal intervals of independent variable.
Relative spectral transmission of the atmosphere.
The two common failures of the Clark standard cell.
Measurement of diffuse reflection factors and a new absolute reflectometer (with bibliography).
A photographic method of detecting changes in a complicated group of objects.
Measurements on the thermal dilatation of glass at high temperatures.
Air forces on circular cylinders, axes normal to the wind, with special reference to dynamical similarity.
Relation of the high-temperature treatment of high-speed steel to secondary hardening and red-hardness.
Thermal and physical changes accompanying the heating of hardened carbon steels.
A study of the relation between the Brinell hardness and the grain size of annealed carbon steels.
Positive and negative photoelectrical properties of molybdenite and several other substances.
Metallographic etching reagents: I, for copper.
Ionization and resonance potentials of some nonmetallic elements.

Infra-red transmission and refraction data on standard lens and prism material (with bibliography).
Use of ammonium persulphate for revealing the macrostructure of iron and steel.
Resonance potentials and low-voltage arcs for metals of the second group of the periodic table.
Magnetic reluctivity relationship as related to certain structures of a eutectoid-carbon steel.
A simple portable instrument for the absolute measurement of reflection and transmission factors.
Present status of the constants and verification of the laws of thermal radiation of a uniformly heated inclosure (with bibliography).
Recent modifications in the construction of platinum resistance thermometers.
Effect of the rate of cooling on the magnetic and other properties of an annealed eutectoid-carbon steel.
A new method for the measurement of photographic filter factors.
Thermal expansion of copper and some of its important industrial alloys.
Wave-length measurements in arc spectra photographed in the yellow, red, and infra-red.
Spectrophotoelectrical sensitivity of proustite.

TECHNOLOGIC PAPERS.

Saybolt viscosity of blends.
Enamels for sheet iron and steel.
Laboratory wearing test to determine the relative wear resistance of sole leather at different depths throughout the thickness of a hide.
An examination of the Munsell color system: I, Spectral and total reflection and the Munsell scale of value.
Color and spectral composition of certain high-intensity searchlight arcs.
Measurement of plasticity of mortars and plasters.
Pyrometric practice.
Automatic apparatus for intermittent testing.
Cast iron for locomotive-cylinder parts.
Tests of bond resistance between concrete and steel.
Effects of Cal as an accelerator of the hardening of Portland cement mixtures.
Pouring and pressure tests of concrete.
Slushing oils.
Sulphur in petroleum oils.
Steel rails from sink-head and ordinary rail ingots.
Electric-arc welding of steel: I, Properties of the arc-fused metal (with bibliography).
Causes and prevention of the formation of noncondensible gases in ammonia absorption refrigeration machines.
Colored wall plaster.
Effect of repeated reversals of stress on double-reinforced concrete beams.
Notes on small flow meters for air, especially orifice meters.
Fire tests of building columns.
Experiments on copper crusher cylinders.
Oscillograph measurements of the instantaneous values of current and voltage in the battery circuit of automobiles.
A study of test methods for the purpose of developing standard specifications for paper bags for cement and lime.
Some properties of white metal bearing alloys at elevated temperatures.
Method for differentiating and estimating unbleached sulphite and sulphate pulps in paper.
"Black nickel" plating solutions.

CIRCULARS.

Operation and care of vehicle-type batteries (with glossary).
Inks: Their composition, manufacture, and methods of testing.
Recommended specifications for green paint, semipaste and ready-mixed.
Recommended specifications for volatile mineral spirits for thinning paints.
Carbonization of lubricating oils.
Nickel (with bibliography).

Physical properties of materials: I, Strengths and related properties of metals and certain other engineering materials.
Recommended specification for composite thinner for thinning semipaste paints when the use of straight linseed oil is not justified.
Recommended specification for spar varnish.
Recommended specification for asphalt varnish.
Recommended specification for liquid paint dryer.
Lime: Definitions and specifications.
The testing of paper.
Gypsum: Properties, definitions, and uses.
Sand-lime brick: Description and specification.
Specifications for marine sextants.
Recommended specification for flat interior lithophone paint, white and light tints.

HANDBOOKS.

National safety code for protection of the heads and eyes of industrial workers.
National electrical safety code.
Discussion of the national electrical safety code.

MISCELLANEOUS PUBLICATIONS.

Progress report of National Screw Thread Commission.
Weights and measures: Thirteenth annual conference of representatives from various States held at Bureau, Washington, D. C., May 24–27, 1920.
Annual report of Director, 1920.
Buying commodities by weight or measure (extracts adapted from Bureau Circular 55, Measurements for the household).
War work of Bureau.

IV. ENGINEERING AND CONSTRUCTION.

This division is concerned with the operation and maintenance of the power plant, the installation and repair of electrical equipment and plumbing, and with the care of the buildings and grounds.

OPERATION AND MAINTENANCE OF MECHANICAL PLANT.

Operation of Plant.

The mechanical plant comprises the heating, generating, and refrigeration equipment; compressed air, vacuum and high-pressure water services, and storage batteries, stationary and portable. There were practically no additions of any importance to the mechanical plant equipment during the past year. One soot blower was installed on No. 5 boiler, and boilers Nos. 3, 4, and 5 were equipped with feedwater regulators. The work of greatest moment to this section during the year was the installation of a duplicate feeder for emergency service which has recently been completed. Interruptions in the service, which in the beginning of the fiscal year were very frequent, have steadily declined. It is hoped that the emergency feeder will provide for practically continuous service. The frequency changer for securing 3-phase 60-cycle power has become seriously overloaded. Steps are being taken toward securing a larger unit of similar design.

CONSTRUCTION AND REPAIR.

Electrical.

The installation, extension, and repair of all electrical wiring, switchboards, motors, and similar equipment for the various laboratories, as well as for the mechanical plant, are performed by this section. Work was continued upon equipping the laboratories in the industrial building and the installations of permanent wiring in the dynamometer laboratory. The paper mill and laboratory and the cotton mill in the industrial building were fully equipped. Numerous small jobs widely distributed but less extensive were also completed. Owing to the smaller demand for new electric construction work a great deal of progress was made on overhauling plant equipment. A cable system is being designed for signals, watchman's electrical clock stations, etc., which it is hoped may be installed in the near future.

Plumbing and Pipe Fitting.

This section is concerned with the installation, maintenance, and repair of all pipe work required for the distribution and use of water, steam, gas, air, vacuum, and refrigeration services, as well as piping required in connection with the power-plant equipment. During the past year larger jobs of new construction included the installation of about 40 emergency safety showers in the chemical laboratory, the complete equipment of cooling chambers and other piping in the aeronautic instruments laboratory, additional radiators for adequate heating of the west side of the west building, and an auxiliary steam

main for the chemical laboratory, which main will amply provide for the summer requirements of that building. Numerous small construction jobs were completed and a great deal of progress was made on plant maintenance and repair work.

BUILDINGS AND GROUNDS.

Grounds.

Some progress has been made in the improvement of the appearance of the grounds. Grading was carried out south and east of the industrial building, east of the chemistry laboratory, and west of the northwest building.

V. GENERAL RECOMMENDATIONS.

Salaries.

I must again call attention to a serious condition which has been mentioned in the last three reports of this Bureau, but unfortunately without effect, namely, the great disparity between the salaries paid scientific and technical experts in the Government service and men engaged in similar work for industrial concerns and educational institutions. This is a real menace to the research work of the Government, which in time will be felt by every industry and individual throughout the country.

While, as mentioned in the introductory chapter of this report, the Bureau can offer a reasonably good entrance salary to young men just out of college, it can not compete on anything like equal terms with outside organizations when the more responsible positions are considered. The men in these positions are among the most valuable in the Government's employ, and many have voluntarily remained in the service from a sense of patriotic duty and at large financial sacrifices. On the other hand, a large number have been forced to accept positions with private corporations, schools, and colleges, although in doing so they realize that the opportunities for research will be far less than in a National institution.

There should be no need for such sacrifices as those just mentioned. The Government can afford to pay and should pay its experts a salary on a plane with that which they can earn in private employment. This matter is particularly serious in the case of the Bureau of Standards, as its sole product is scientific information, which is dependent entirely upon scientific research of the highest grade. Many of the investigations necessarily cover long periods, and the loss of the expert in charge may be equivalent to setting back the whole investigation for a year. It is earnestly recommended that steps be taken immediately to remedy this situation, the seriousness of which is becoming greater each year.

Power Plant.

As pointed out in the reports for 1919 and 1920, the power plant of the Bureau of Standards has for several years been inadequate to meet the demands made upon it. The original plant was well adapted to take care of the requirements of the Bureau at the time it was built, but the institution has now completely outgrown the equipment. It has been necessary to install two additional boiler plants to furnish sufficient steam for heating purposes, and the greater part of the electrical service for power and light is now bought from the local power company. Such decentralization is wasteful and unsatisfactory. It is a well-known fact that a number of small units are far less economical than a larger central plant. Commercial electric power is poorly adapted to supply exacting laboratory requirements. Interruptions to such service can not be avoided, and such cessations of the power supply may mean the loss

of valuable experimental data through the shutting down of laboratory equipment.

A modern central power plant capable of supplying all the necessities of the Bureau in the way of heat, light, power, refrigeration, compressed air, and vacuum services should be constructed as soon as possible. The first cost of such a plant would be saved in a short time through greater economy in power production and more satisfactory service.

Care of Buildings.

The number of janitors, laborers, and watchmen necessary to properly care for the buildings and grounds is still entirely inadequate. As stated in the previous report, laboratories require considerably more janitor and watchman service than ordinary buildings. The nature of the work is such that it requires constant care to keep the buildings in order. Many experiments require continuous operation of some sort, and in buildings where such work is in progress watchmen must be constantly on the alert. The watchmen must use intelligence in case of accident and give attention to continuous operations. To curtail necessary services of this character is questionable economy, and it is a well-known fact that lack of such service has resulted in accidents, thefts, and poor upkeep of buildings.

Buildings and Grounds.

It is recommended that provision be made by Congress for the purchase of the land between the present boundary of the Bureau's property and Connecticut Avenue on the east. This tract is needed to round out the site, and as it will without doubt be purchased eventually it would be better to secure it now before it is built upon.

Although some progress has been made during the year in grading and clearing up the grounds and in the construction of short stretches of permanent road a more adequate fund should be provided for this purpose.

Respectfully,

S. W. Stratton,
Director

To Hon. Herbert Hoover,
Secretary of Commerce.

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